

# APPENDIX H

Report on Effects of Delta Outflow

# San Francisco Bay Area Environmental Management Plan

October 1978

INSTITUTE OF GOVERNMENTAL  
STUDIES LIBRARY

AUG - 1 1980

UNIVERSITY OF CALIFORNIA



This plan was prepared by the Association of Bay Area Governments with a grant and other assistance from the Environmental Protection Agency, in cooperation with Bay Area Air Pollution Control District, Metropolitan Transportation Commission, San Francisco Bay Regional Water Quality Control Board and Counties of the Bay Area with assistance of these agencies: ■ Army Corps of Engineers ■ California Air Resources Board ■ California Department of Health ■ California Department of Transportation ■ Council of Bay Area Resource Conservation Districts ■ Governor's Office of Planning and Research ■ Lawrence Berkeley Laboratory ■ Lawrence Livermore Laboratory ■ San Francisco Bay Conservation and Development Commission ■ State Water Resources Control Board ■ State Solid Waste Management Board ■ Wastewater Solids Study



Digitized by the Internet Archive  
in 2025 with funding from  
State of California and California State Library

<https://archive.org/details/C124924450>

## APPENDIX H

### TECHNICAL REPORT ON THE EFFECTS OF DELTA OUTFLOW ON THE SAN FRANCISCO BAY SYSTEM

This report was prepared for the Association of Bay Area Governments by J.B. Gilbert and Associates. The material in the report was the basis for the recommendations in the Water Quality and Continuing Planning Process chapters of the Environmental Management Plan, June 1978.



## TABLE OF CONTENTS

### CHAPTER I INTRODUCTION

Study Background.....	I-1
Objectives of the Study.....	I-1
Organization of Report.....	I-2

### CHAPTER II SAN FRANCISCO BAY

Areal Extent.....	II-1
Physical Characteristics.....	II-1
Hydrography.....	II-4
Hydrology.....	II-6
Factors Influencing Water Quality.....	II-7
Water Quality Characteristics.....	II-16
Fish and Wildlife Resources.....	II-19
Sediments.....	II-24
Suisun Marsh.....	II-24
Regulatory Authority.....	II-27
Water Quality Objectives.....	II-32

### CHAPTER III SACRAMENTO-SAN JOAQUIN DELTA

Land Resources.....	III-1
Tributary Flow Sources.....	III-5
Water Exportations.....	III-6
Internal Water Use.....	III-17
Historical Net Delta Outflow.....	III-17
Delta Inflow Water Quality.....	III-27
Delta Outflow Water Quality.....	III-44
Water Management Practices.....	III-53
Regulatory Requirements.....	III-58

### CHAPTER IV DELTA OUTFLOW-BAY ENVIRONMENTAL QUALITY RELATIONSHIPS

Predicted Future Outflows.....	IV-1
Hydraulic Considerations.....	IV-3
Environmental Quality Considerations.....	IV-6

**CHAPTER V**  
**PRINCIPAL FINDINGS AND CONCLUSIONS**

Historical and Projected Delta Outflows.....	V-1
Effect of Delta Outflow on Fish.....	V-2
Silicate Contributions to the Bay.....	V-2
Algae Production and Assimilation of Pollutants.....	V-2
Effect on Stratification.....	V-3
Need for Further Research.....	V-3

**APPENDIX A**  
**REFERENCES**

**APPENDIX B**

**DERIVATION OF RELATIONSHIPS BETWEEN VARIOUS WATER QUALITY  
PARAMETERS AND DELTA OUTFLOW FOR NORTHERN SAN FRANCISCO BAY**

## LIST OF TABLES

TABLE II-1 ESTIMATED MUNICIPAL AND NONDISCRETE INDUSTRIAL WASTEWATER LOADS AFTER TREATMENT IN 1975.....	II-9
TABLE II-2 ESTIMATED DISCRETE INDUSTRIAL WASTEWATER LOADS AFTER TREATMENT IN 1975.....	II-10
TABLE II-3 MEAN FLOWS FROM MAJOR DRAINAGE BASINS.....	II-11
TABLE II-4 STORM WATER RUNOFF POLLUTANT LOADS TRIBUTARY TO SAN FRANCISCO BAY.....	II-13
TABLE II-5 ESTIMATED PRESENT WASTE LOADS FROM VESSELS.....	II-14
TABLE II-6 ESTIMATED POLLUTION LOADS DISCHARGED TO SAN FRANCISCO BAY FROM AERIAL FALLOUT.....	II-15
TABLE II-7 SUMMARY COMPARISON OF 1975 POLLUTANT LOADS DISCHARGED TO THE SAN FRANCISCO BAY SYSTEM.....	II-15
TABLE II-8 SUMMARY OF WATER QUALITY CHARACTERISTICS OBSERVED IN SAN FRANCISCO BAY.....	II-17
TABLE II-9 LIST OF RARE AND ENDANGERED SPECIES FOR BASIN 2 AND ADJACENT OCEAN WATERS.....	II-25
TABLE II-10 SUMMARY OF SEDIMENT QUALITY CHARACTERISTICS OBSERVED IN SAN FRANCISCO BAY.....	II-26
TABLE II-11 EXISTING AND POTENTIAL BENEFICIAL USES OF SAN FRANCISCO BAY WATERS.....	II-33

TABLE III-1 RECLAMATION BY DECADE IN THE SACRAMENTO-SAN JOAQUIN DELTA.....	III-4
TABLE III-2 SACRAMENTO-SAN JOAQUIN DELTA ESTIMATED HISTORIC TRIBUTARY FLOWS.....	III-7
TABLE III-3 CENTRAL VALLEY PROJECT STORAGE FACILITIES.....	III-11
TABLE III-4 STATE WATER PROJECT MAJOR STORAGE FACILITIES.....	III-13
TABLE III-5 SUMMARY OF WATER EXPORTS, SACRAMENTO-SAN JOAQUIN DELTA...	III-15
TABLE III-6 ESTIMATED HISTORIC DELTA INTERNAL NET USE.....	III-18
TABLE III-7 SUMMARY OF HISTORICAL ANNUAL WATER QUALITY OF SACRAMENTO RIVER AT FREEPORT.....	III-28
TABLE III-8 SUMMARY OF HISTORICAL ANNUAL WATER QUALITY OF SAN JOAQUIN RIVER AT MOSSDALE BRIDGE.....	III-31
TABLE III-9 SUMMARY OF HISTORICAL ANNUAL WATER QUALITY OF MOKELEMUNE RIVER AT WOODBRIDGE.....	III-36
TABLE III-10 SUMMARY OF HISTORICAL ANNUAL WATER QUALITY OF CALAVERAS RIVER NEAR JENNY LIND.....	III-41
TABLE III-11 SUMMARY OF HISTORICAL ANNUAL WATER QUALITY OF COSUMNES RIVER AT McCONNELL.....	III-45
TABLE III-12 SUMMARY OF HISTORICAL ANNUAL WATER QUALITY OF DELTA OUTFLOW, SACRAMENTO RIVER AT CHIPPS ISLAND.....	III-48

TABLE III-13 ESTIMATED ANNUAL AMOUNTS OF WATER EXPORTED FROM THE DELTA.....	III-56
TABLE III-14 SUMMARY OF DELTA SALINITY AND ENVIRONMENTAL CRITERIA RELATED TO WATER DEVELOPMENT IN THE DELTA AREA.....	III-59
TABLE IV-1 SUMMARY OF DELTA OUTFLOW OVER TIME.....	IV-2
TABLE IV-2 MONTHLY SILICATE CONTRIBUTIONS TO SAN FRANCISCO BAY.....	IV-12
TABLE IV-3 HISTORICAL MEAN BAY SUSPENDED SOLIDS CONCENTRATIONS AND SECCHI DISC TRANSPARENCIES FOR TWO DIFFERENT LEVELS OF DELTA OUTFLOW.....	IV-16

## LIST OF FIGURES

FIGURE II-1 SAN FRANCISCO BAY SYSTEM.....	II-2
FIGURE II-2 MEAN TIDAL RANGES WITHIN THE SAN FRANCISCO BAY SYSTEM....	II-5
FIGURE II-3 LOWER TEN PERCENTILE DISSOLVED OXYGEN CONCENTRATIONS FOR WATERS DESIGNATED AS AQUATIC LIFE HABITAT.....	II-38
FIGURE III-1 SACRAMENTO-SAN JOAQUIN DELTA SUISUN MARSH.....	III-2
FIGURE III-2 CENTRAL VALLEY DRAINAGE AND WATER STORAGE AND EXPORT FACILITIES.....	III-3
FIGURE III-3 ESTIMATED ANNUAL HISTORIC DELTA INFLOW FROM ENTIRE CENTRAL VALLEY.....	III-9
FIGURE III-4 TOTAL ANNUAL HISTORIC DELTA EXPORT.....	III-16
FIGURE III-5 ESTIMATED ANNUAL HISTORIC DELTA NET INTERNAL USE.....	III-19
FIGURE III-6 ESTIMATED HISTORIC AVERAGE ANNUAL NET DELTA OUTFLOW AT CHIPPS ISLAND.....	III-21
FIGURE III-7 ESTIMATED HISTORIC MONTHLY DELTA WATER SUPPLY AND DISPOSAL.....	III-22
FIGURE III-8 HISTORIC MAXIMUM MONTH NET DELTA OUTFLOW AT CHIPPS ISLAND.....	III-23

FIGURE III-9 HISTORIC MINIMUM MONTH NET DELTA OUTFLOW AT CHIPPS ISLAND.....	III-25
FIGURE III-10 ESTIMATED HISTORIC NET DELTA OUTFLOW CRITICAL PERIOD (1928-29 through 1933-34) .....	III-26
FIGURE III-11 RELATIONSHIP BETWEEN ELECTRICAL CONDUCTIVITY, CHLOROSITY, TURBIDITY, AND DELTA OUTFLOW INDEX AT CHIPPS ISLAND.....	III-50
FIGURE III-12 RELATIONSHIP BETWEEN NUTRIENT CONCENTRATION AND DELTA OUTFLOW INDEX AT CHIPPS ISLAND.....	III-52
FIGURE IV-1 RESIDENCE AND HYDRAULIC DISPLACEMENT TIME IN NORTHERN REACH, 1961-1962 WATER YEAR.....	IV-5
FIGURE IV-2 DISTRIBUTION OF CHLOROSITY IN NORTHERN SAN FRANCISCO BAY AS A FUNCTION OF NET DELTA OUTFLOW.....	IV-7
FIGURE IV-3 LOCATION OF SAMPLING STATIONS, NORTHERN SAN FRANCISCO BAY.....	IV-8
FIGURE IV-4 DISTRIBUTION OF SILICA IN NORTHERN SAN FRANCISCO BAY AS A FUNCTION OF NET DELTA OUTFLOW.....	IV-13
FIGURE IV-5 DISTRIBUTION OF TOTAL SUSPENDED SOLIDS IN NORTHERN SAN FRANCISCO BAY AS A FUNCTION OF NET DELTA OUTFLOW.....	IV-15
FIGURE B-1 NET TRAVEL TIME FROM SACRAMENTO RIVER GAGING STATION AT SACRAMENTO TO VARIOUS LOCATIONS IN NORTHERN SAN FRANCISCO BAY AS A FUNCTION OF NET DELTA OUTFLOW.....	B-2



## CHAPTER I

### INTRODUCTION

#### STUDY BACKGROUND

The U. S. Environmental Protection Agency awarded a contract to the Association of Bay Area Governments (ABAG) to prepare an Environmental Management Plan for the San Francisco Bay Region under Section 208 of the Federal Water Pollution Control Act Amendments of 1972. This plan will have four major management elements addressing water quality, water supply, solid waste, and air quality.

Major water-related studies are being conducted on surface runoff; municipal wastewater facilities; industrial wastewater discharges; water conservation, reuse, and supply; and nonpoint water pollution sources other than surface runoff. In addition, ABAG directed that a number of special studies be conducted to assemble and evaluate available information on San Francisco Bay. The special studies were:

1. Delta outflow;
2. Shellfish contamination;
3. Eutrophication;
4. Effects of toxicants;
5. Fish kills; and
6. Dredging and disposal.

These special studies had the common general objective of identifying problems in San Francisco Bay and especially critical problems that might be affected by control measures proposed in the Environmental Management Plan.

#### OBJECTIVES OF THE STUDY

The general purpose of this study was to examine the issues related to future freshwater outflows from the Central Valley through the Sacramento-San Joaquin Delta into San Francisco Bay. The issues relate primarily to future upstream regulation and diversion that might be imposed affecting two outflow conditions: high winter or flood flows, and minimum or low dry season flows.

Specific objectives of the study were to:

1. Define Delta outflow characteristics.
2. Determine the effect of Delta outflow on San Francisco Bay water quality.

Because it was recognized that there was no established theory or mathematical relationships that could be combined with available data to support any major new revelations on the effects of Delta outflow on Bay water quality, the study was directed to review of analyses of work recently completed and compilation of available facts.

#### ORGANIZATION OF REPORT

This report is divided into five chapters; Chapter II describes conditions in San Francisco Bay; Chapter III describes conditions in the Sacramento-San Joaquin Delta; Chapter IV relates the Bay and Delta; and Chapter V summarizes the principal findings and conclusions. The description of San Francisco Bay emphasizes the present water quality, the laws and regulations shaping local water quality management, and the water quality objectives set for the Bay to protect established or potential beneficial uses. Principal conditions in the Delta of concern are historical amounts of freshwater inflows, diversions, and subsequent outflows and the quality of these waters together with the regulatory framework within which these flows are managed. Environmental quality relationships are developed in Chapter IV showing the importance of Delta outflow on water circulation, water quality, fish, and other Bay characteristics.

## CHAPTER II

### SAN FRANCISCO BAY

San Francisco Bay lies in a unique natural setting on the Central Coast of California. As shown on Figure II-1, the Bay system consists of Honker, Grizzly, and Suisun bays (generally referred to simply as Suisun Bay), Carquinez Strait, San Pablo Bay, and Central and South San Francisco Bay. The system has a total surface area of about 421 square miles at mean tide level (Selleck et al., 1966a). The Bay functions as the only drainage outlet for the two major rivers--the Sacramento and the San Joaquin--that drain the Central Valley of California. The combined drainage area contributary to these rivers is about 45,400 square miles. The Bay also marks the only break in the Coast Ranges which form a nearly continuous north-south barrier between the Pacific Ocean and the Central Valley.

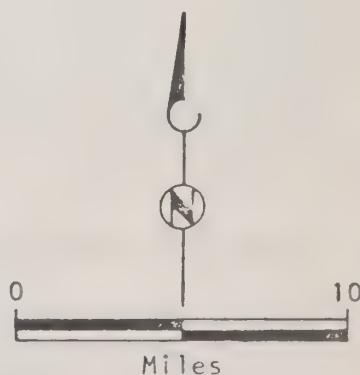
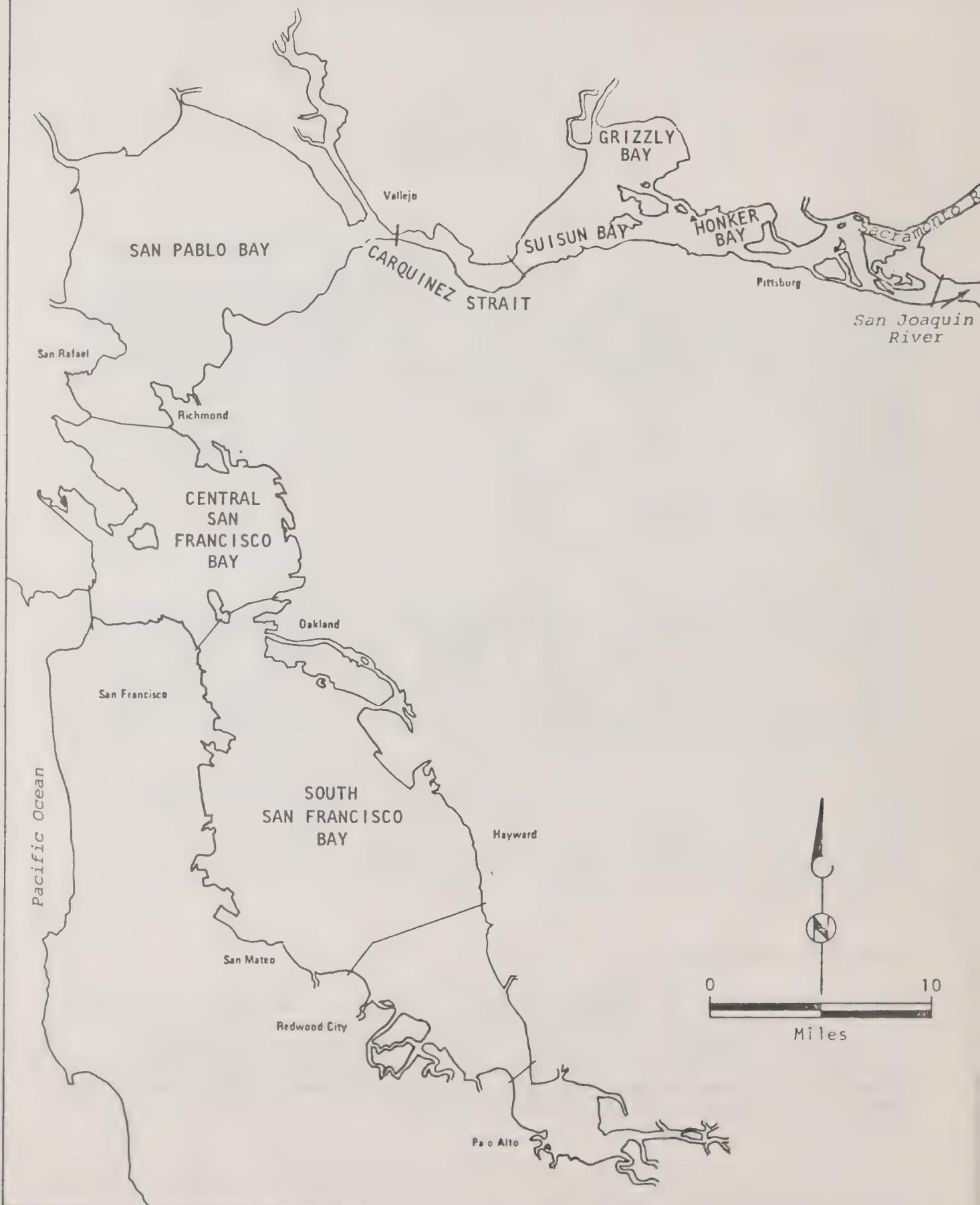
#### AREAL EXTENT

Within the confines of the San Francisco Bay system, seaward of Chipps Island, there are eighty separate drainage basins comprising a total drainage area of about 3,507 square miles. The seven largest drainage basins comprise about 39 percent of the total. In decreasing order of size these basins are: Alameda Creek, Napa River, Coyote Creek, Guadalupe River, Walnut Creek, Sonoma Creek, and Petaluma River.

About 100 years ago the San Francisco Bay system had a total surface area of nearly 700 square miles including more than 300 square miles of marshland. Today, however, almost 80 percent of the marshland has been "reclaimed" for agricultural purposes, salt ponds, and some residential and commercial developments (SWRCB, 1975).

#### PHYSICAL CHARACTERISTICS

The unusual physical characteristics of the Bay system contribute to the diversity of indigenous habitat. Deepwater areas exist within each segment of the Bay adjacent to large expanses of very shallow water. A wide spectrum of salinity, ranging from seawater to fresh water, is nearly always present; wide ranges of water temperature are also encountered.



SAN FRANCISCO BAY SYSTEM  
JBGA/DLF/RTC 7/77

FIGURE 11-1

### Suisun Bay

The Suisun Bay area, which includes Honker, Grizzly, and Suisun bays, is essentially an extension of the combined Sacramento and San Joaquin River channels. It has a width of about three miles, a length of about 10 miles, and a depth ranging from three to 40 feet.

Adjoining Suisun Bay on the north are two relatively shallow embayments--Grizzly Bay and Honker Bay. These two embayments comprise the major portion of the 25,000-acre open water area of Suisun Bay at mean tide level. Although there is a minimum amount of tidal flat exposure in Suisun Bay (about 2,000 acres), about 36 percent of the total area is less than three feet deep and about 50 percent is less than eight feet deep (SERL, 1966a).

Adjoining the north shores of Suisun Bay is an extensive area of marsh lands consisting of numerous islands separated by an extensive network of channels. This area, covering about 85,000 acres, is the Suisun Marsh, which is the largest contiguous freshwater marsh in the continental United States.

### Carquinez Strait

Carquinez Strait connects Suisun Bay with San Pablo Bay. It is about seven miles in length, and is from one-half to one and one-half miles in width. Depths generally range from 40 to 90 feet.

The water surface area of Carquinez Strait is about 3,700 acres at mean tidal level (SERL, 1966a).

### San Pablo Bay

San Pablo Bay is a shallow circular basin traversed by a deepwater channel near its southeastern shore. San Pablo Bay covers some 65,000 acres at mean tide level, which represents about 24 percent of the entire Bay surface area. During mean high tide, however, the surface area of San Pablo Bay increases to nearly 68,000 acres. Most of San Pablo Bay is relatively shallow, with approximately one-half of it being less than six feet deep at mean lower-low water (SERL, 1966a).

The Bay acts as a large settling basin for the heavy silt loads which accompany high Delta outflows. Large quantities of silt are deposited in San Pablo Bay and are subsequently distributed by tidal action to form the large shallow areas of the Bay.

### Central San Francisco Bay

Central San Francisco Bay, hereafter referred to as Central Bay, extends from Point Richmond to the San Francisco-Oakland Bay Bridge. This portion of the Bay system comprises about 56,000 acres at mean tide, or about 20 percent of the entire Bay system. It is also the deepest portion of the Bay, averaging about 40 feet of depth at mean lower-low water (SERL, 1966a).

### South San Francisco Bay

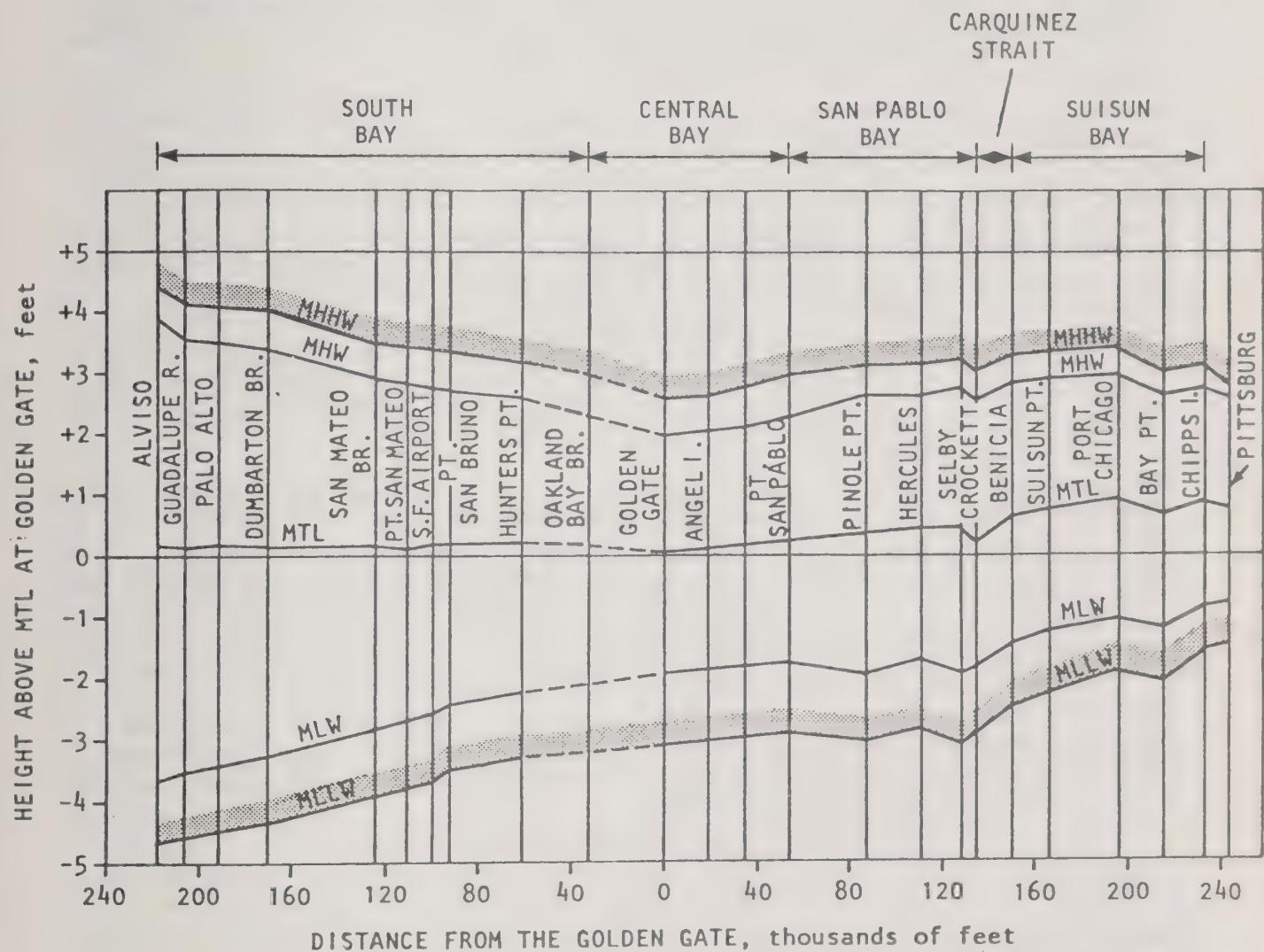
South San Francisco Bay, hereafter designated South Bay, is by far the largest portion of San Francisco Bay, comprising about 121,000 acres at mean tide level, or about 45 percent of the total Bay surface area. This portion of the Bay is relatively shallow, averaging only 15 feet of depth at mean lower-low water. A distinct physical feature of the South Bay is the expanse of mud flats (about 21,000 acres), which is exposed at low tide (SERL, 1966a).

## HYDROGRAPHY

Along the central California coast, the tides are of the mixed type, producing two high and two low waters each tidal day (24.8 hours) with a variable diurnal inequality. The amount of inequality varies considerably within the lunar month and ranges from approximately equal tides to a maximum inequality of over five feet between successive low tides. Tidal range, as measured from mean high water to mean low water, seldom exceeds eight feet, and the mean range is about four feet.

In the southern reach of the Bay the tides and tidal currents have characteristics similar to a standing wave. As a result, the mean tidal range is amplified to about seven and one-half feet at the end of South Bay, near the mouth of Coyote Creek. In the northern reach of the Bay, however, the tidal wave is progressively damped so that at Antioch the tidal range is little more than three feet. Tidal ranges throughout the Bay system are shown on Figure II-2.

Tidal ebb and flow is the single factor of overriding importance in the movement of water through the Bay. Compared to the volume of the tidal prism (about 50 billion cubic feet), the historic maximum outflow of fresh water through the Bay is of similar



SOURCE: U.S. ARMY, CORPS OF ENGINEERS, Technical Report on Barriers, Appendix H, Volumes I and II, San Francisco, California, March 1963

MEAN TIDAL RANGES  
WITHIN THE SAN FRANCISCO BAY SYSTEM  
JBGA/DLF/RTC 7/77

FIGURE 11-2

magnitude, but smaller. Although the seasons do cause some changes in water quality and modify the pattern of mass water movement, the basic flow patterns are tidally induced and remain relatively unchanged throughout the year.

In the northern reach of San Francisco Bay, the advective flow (movement of water resulting from causes other than the tides) is primarily the result of Delta outflow. Local runoff, precipitation, evaporation, groundwater movement, and waste discharges play minor roles. However, in the southern reach there is very little inflow from natural streams. Therefore, waste discharges and evaporation are important factors in producing advective flows. Because of the high evaporation rates and the lack of freshwater inflow to the southern end of the Bay, the net advective flow in relation to the Golden Gate is southward during the summer instead of northward. In other words, the South Bay is a negative estuary during the summer months.

The residence time for water quality constituents in a particular body of water can be defined as the average length of time that a constituent or particle remains within the water body. This residence time is a function of the combined effects of advective flow, tidal exchange, dispersion or mixing, and the locations of sources and sinks of the constituents being considered. Because the South Bay is often a negative estuary, residence times in this section of the Bay are extremely long; on the order of several months or more. In the North Bay, residence times are shorter; however, even in this section of the Bay the residence times depend strongly on Delta outflow and can be quite long when Delta outflows are at a minimum.

## HYDROLOGY

Seasonal precipitation--84 percent normally falls during the period November through March--in the local San Francisco Bay watershed results in maximum runoff during the winter and spring and minimum stream flows during the summer and fall. In addition, almost every major stream tributary to the Bay is subject to upstream regulation by storage and diversion.

Excluding the Delta and regions draining directly to the Pacific Ocean, the total local watershed area of the San Francisco Bay system is 3,928 square miles, of which 3,507 square miles are land area and 421 square miles are water surface (at mean tide level). The major watershed areas contributing fresh water to

the Bay are those of the Sacramento River (26,322 square miles) and the San Joaquin River (19,096 square miles). The combined average discharge of the two rivers, about 29,000 cubic feet per second (cfs) dwarfs the flow of the next largest tributary to the Bay, namely Alameda Creek (633 square miles), whose average annual discharge is only 121 cfs.

#### FACTORS INFLUENCING WATER QUALITY

Many factors influence the quality of San Francisco Bay waters. Some of the more obvious factors are: Delta outflow, tidal exchange, salinity stratification, municipal waste discharges, industrial waste discharges, surface water runoff, storm water runoff, agricultural return water, marine vessel discharges, accidental spills, aerial fallout, and dredging spoils. These factors are discussed in the following paragraphs.

##### Delta Outflow

Approximately 98 percent of the total freshwater inflow to the San Francisco Bay system is provided by the outflow from the Sacramento-San Joaquin Delta. Therefore, diversions of water from the Delta by the Central Valley Project and the State Water Project, which in turn reduce Delta outflows, deserve serious attention.

In the past, concern for the proper management of water resources in the Delta has been intense, but has focused on the impact of management activities on water quality in the Delta rather than in the Bay. For instance, the State Water Resources Control Board has established salinity standards for the Delta primarily for the protection of aquatic life and agricultural uses. In order to comply with these standards it will be necessary for the project operators to maintain a certain net Delta outflow.

##### Tidal Exchange

Tidal ebb and flow is the most important factor with regard to the movement of water through the Bay. The tidal prism represents about 21 percent of the volume of water in the Bay system at mean tide. Although the seasons cause some changes in water quality and modify the pattern of mass water movement, the basic flow patterns are tidally induced and remain relatively unchanged throughout the year.

### Salinity Stratification

High winter outflows of fresh water from the Delta tend to flow on top of the heavier salt water of San Francisco Bay. Tides and winds normally mix the two, but when outflows are large, this mixing is incomplete and the Bay becomes "stratified" (i.e., low salinity near the surface and high salinity near the bottom). Such salinity stratification has always occurred in Suisun, San Pablo, and Central San Francisco bays for several months during most years, and has at times extended into South Bay during periods of very high runoff.

This salinity stratification is important with respect to water quality as it creates circulating currents through the estuary which in turn transport suspended and dissolved materials downstream near the surface and upstream near the bottom. Both surface and bottom currents move back and forth with the tides, but on flood tides currents are stronger near the bottom and on ebb tides they are stronger near the surface. When stratified, current velocities are faster and residence times of any transportable materials in any one location are shorter than if the fresh and salt water were completely mixed and there was a simple back and forth, but net seaward, movement of the mix with changing tides. Such circulation has been names as important for flushing pollutants from the system, for controlling basic biological productivity, and for transporting and distributing larval invertebrates, fish, and their food supplies (Kelley, 1977).

### Municipal Waste Discharges

Approximately 485 million gallons of municipal and industrial wastewater are conveyed in municipal sewers, treated, and discharged into San Francisco Bay and its tributaries, downstream of Chipps Island, daily. Presently, these discharges include about 355,000 pounds of biochemical oxygen demand, 221,000 pounds of suspended solids, 113,000 pounds of nitrogen, of which 75,100 pounds are ammonia, and 62,100 pounds of total phosphorus. A breakdown of these pollutant loads by county is presented in Table II-1, which indicates that the pollutant loads discharged from municipal wastewater treatment plants to the Bay are significant.

TABLE II-1

ESTIMATED MUNICIPAL AND NONDISCRETE INDUSTRIAL  
WASTEWATER LOADS AFTER TREATMENT IN 1975\*

County	Flow ADWF, mgd	BOD <sub>5</sub> lb/day	TSS lb/day	TN lb/day	NH <sub>3</sub> -N lb/day	TP lb/day
Marin	19.0	6,494	4,934	4,850	3,562	2,183
Sonoma	5.6	1,973	3,374	1,399	1,165	979
Napa	5.7	1,046	3,090	475	48	238
Solano	17.9	11,694	13,295	4,167	2,636	1,739
Contra Costa	46.2	34,144	23,796	10,975	7,832	4,395
Alameda	123.7	150,888	80,503	32,204	19,043	19,432
Santa Clara	136.7	31,361	32,019	28,606	21,922	21,210
San Mateo	47.8	38,858	21,726	12,698	8,022	6,619
San Francisco	82.6	78,111	38,714	17,725	10,841	5,340
Total	485.2	354,569	221,451	113,099	75,071	62,135

Source: Association of Bay Area Governments Tech Memo 30/January 1978

\*Tributary to San Francisco Bay only, downstream of Chipps Island.

Industrial Waste Discharges

Approximately 45 million gallons of industrial process water is discharged to the San Francisco Bay system downstream of Chipps Island on a daily basis. In addition, about 860 million gallons are withdrawn, used for once-through cooling, and returned to the Bay downstream of Chipps Island on a daily basis. The 45 million gallons of process water contains about 31,500 pounds of biochemical oxygen demand, 24,000 pounds of total suspended solids, 4,010 pounds of total nitrogen, of which 3,410 pounds are in the form of ammonia, and 185 pounds of total phosphorus. A breakdown of these pollutant loads by county is presented in Table II-2, which indicates that the pollutant loads discharged from industrial wastewater treatment plants to the Bay system are much less than from municipal wastewater treatment plants.

TABLE II-2

ESTIMATED DISCRETE INDUSTRIAL WASTEWATER LOADS  
AFTER TREATMENT IN 1975\*

County	Flow		BOD <sub>5</sub> lb/day	TSS lb/day	TN lb/day	NH <sub>3</sub> -N lb/day	TP lb/day
	Process mgd	Once-through cooling mgd					
Marin	0	0	0	0	0	0	0
Sonoma	0	0	0	0	0	0	0
Napa	0	0.4	20	100	5	0	0
Solano	2.3	1.5	510	810	755	740	0
Contra Costa	32.6	238.4	30,300	16,910	3,155	2,660	20
Alameda	8.9	2.8	190	1,475	15	0	160
Santa Clara	0	0	0	0	0	0	0
San Mateo	1.4	4.6	385	2,815	30	5	5
San Francisco	0.2	610.8	130	1,440	50	0	0
Total	45.4	858.5	31,535	23,550	4,010	3,405	185

Source: Association of Bay Area Governments Tech Memo 18/May 77

\*Tributary to San Francisco Bay only, downstream of Chipps Island.

#### Surface Water Runoff

The outflow from the Delta provides about 98 percent of the total fresh water inflow to the Bay system, because the San Francisco Bay basin does not contain any large streams within its boundaries. There are, however, numerous small streams within the basin that are tributary to the Bay. The seven most significant ones are listed in Table II-3, which shows the mean annual and mean monthly runoff from these streams.

As shown in Table II-3, stream flow in the basin is highly seasonal with more than 90 percent of the annual runoff occurring during the period between November and April. Also as shown in Table II-3, many of these streams go dry during the middle or

TABLE II-3

MEAN FLOWS FROM MAJOR DRAINAGE BASINS<sup>a</sup>

Stream and gage location	Drainage area, sq mi	Mean annual flow, cfs	Mean monthly flow, in cfs and as percent of annual											
			Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Guadalupe River <sup>b</sup> at San Jose	144	32.3	73.0 18.6	114.0 29.0	88.0 22.4	65.4 16.6	3.4 0.9	0.4 0.1	0.3 0.1	0.3 0.1	0.2 0.1	3.5 0.9	5.2 1.3	39.4 10.0
Alameda Creek <sup>c</sup> near Niles	633	121	342.0 23.2	423.0 28.8	322.4 22.0	150.0 10.2	34.8 2.4	13.6 0.9	9.3 0.6	6.6 0.4	6.4 0.4	6.8 0.5	29.8 2.0	123.0 8.4
Coyote Creek <sup>d</sup> near Madrone	196	61	37.7 5.1	117.3 16.0	112.0 15.3	96.7 13.2	60.1 8.2	63.2 8.6	57.1 7.8	47.8 6.5	42.5 5.8	39.2 5.4	31.4 4.3	29.0 4.0
Napa River <sup>e</sup> near Napa	218	149	504.0 28.0	453.0 25.1	264.0 14.7	193.0 10.7	37.5 2.1	11.1 0.6	2.6 0.1	1.1 0.1	0.7 0.0	29.5 1.6	33.0 1.8	272.0 15.1
Sonoma Creek near Agua Caliente	58.3	69.2	213.1 25.3	246.4 29.3	110.8 13.2	93.3 11.1	16.0 1.9	5.5 0.6	1.9 0.2	1.0 0.1	0.9 0.1	12.4 1.5	13.4 1.6	126.0 15.0
Petaluma Creek near Petaluma	30.9	17.0	58.7 28.8	64.1 30.2	28.4 13.9	14.0 6.8	0.5 0.2	0.03 0.01	0.0 0.0	0.0 0.0	0.0 0.0	0.9 0.5	2.2 1.1	37.6 18.5
Walnut Creek <sup>f</sup> at Walnut Creek	79.2	28.3	83.1 24.3	71.3 20.9	38.1 11.1	54.2 15.8	11.5 3.3	5.6 1.6	2.9 0.8	2.2 0.6	2.1 0.6	13.9 4.1	7.5 2.2	49.2 14.4
Annual average to San Francisco Bay = 478														

<sup>a</sup>Source: U.S. Department of the Interior, Geological Survey, "California Streamflow Characteristics", Part I, Vol. 2, June 1971.<sup>b</sup>Flow is regulated by Calero, Austrian, Guadalupe, Almaden, and Lexington reservoirs.<sup>c</sup>Flow is regulated by Calaveras, Del Valle, and San Antonio reservoirs and supplemented by releases from South Bay Aqueduct.<sup>d</sup>Flow values are essentially the releases from Anderson Reservoir.<sup>e</sup>Flow is regulated by Lake Hennessey.<sup>f</sup>Flow is slightly regulated by storage in Lafayette Reservoir.Source: Water Quality Control Plan Report, San Francisco Bay Basin (2),  
State Water Resources Control Board, November 1974.

late summer. The Napa River, which is the least affected by upstream regulation, clearly shows the seasonality of runoff; less than five percent of the average annual runoff occurs during the summer months.

Because the flows of these streams are so low they do not have a significant effect on San Francisco Bay water quality except, perhaps, in very localized areas near the points of entry to the Bay.

#### Storm Water Waste Loads

Waste loads attributable to storm water runoff represent a substantial portion of the total sediment, organic, pesticide, and heavy metal loads on receiving waters in the basin (SWRCB, 1975). Materials present in urban runoff originate from various sources, including street litter, soil and debris from vacant lots and yards, building and demolition wastes, materials eroded from pavements, and many other contaminants generated from a diverse variety of man's activities.

As part of its basic planning effort, the State Water Resources Control Board calculated the pollutant loads from storm water runoff in the Bay Area. These pollutant loads are summarized in Table II-4.

#### Agricultural Return Water

Agricultural wastes generated within the San Francisco Bay basin have limited effect on water quality in the Bay (SWRCB, 1975). This is the result of the small size and diffuse occurrence of agricultural operations in this predominantly urban region.

#### Marine Vessel Discharges

The State Water Resources Control Board also estimated the existing waste loads from marine vessels as part of its basin planning effort. Assuming discharge coefficients of 0.10 pounds BOD<sub>5</sub>, 0.02 pounds nitrogen, and 0.0025 pounds phosphorus per capita per day, waste loads generated by vessels in the Bay Area would be as shown in Table II-5.

TABLE II-4

STORM WATER RUNOFF POLLUTANT LOADS  
TRIBUTARY TO SAN FRANCISCO BAY  
(1,000 pounds/year)

	BOD <sub>5</sub>		TN		TP		THM	
	1970	2000	1970	2000	1970	2000	1970	2000
Marin County	1,604.6	3,034.9	433.4	604.0	54.7	94.6	179.2	355.7
Sonoma County	710.0	1,279.0	385.0	372.0	34.0	44.4	73.0	143.2
Napa County	970.0	1,770.0	480.0	580.0	43.0	65.0	99.0	203.0
Solano County	1,125.0	1,773.0	455.6	441.0	46.0	62.6	120.8	200.1
Contra Costa County	3,776.0	5,825.2	853.7	1,064.0	119.4	171.2	446.9	678.7
East Bay	3,317.9	4,399.6	761.0	791.0	101.7	130.8	394.8	512.2
Santa Clara County	4,755.6	7,109.2	1,028.8	1,278.0	147.7	202.6	569.1	832.5
San Mateo County	2,022.1	2,630.1	470.8	522.2	64.0	78.0	233.6	302.0
San Francisco	1,074.0	1,071.0	185.3	181.5	30.8	30.6	122.3	122.0
Totals	19,355.2	28,892.0	5,053.6	5,833.7	641.3	879.8	2,238.7	3,349.4

Source: SWRCB, 1975

BOD<sub>5</sub> = 5-day biochemical oxygen demand

TN = total nitrogen

TP = total phosphorus

THM = representative heavy metals (Cd, Cr, Cu, Pb, Hg, Ni, and Zn)

TABLE II-5  
ESTIMATED PRESENT WASTE  
LOADS FROM VESSELS  
(1,000 pounds/year)

Vessel Type	BOD <sub>5</sub>	Total Nitrogen	Total Phosphorus
Commercial	140	28	3.5
Military	375	74	9.4
Pleasure	120	24	3.0
Total	635	127	15.9

Source: SWRCB, 1975

spills during fuel transferring and bunkering operations. Normally, however, these spills are of small volume (300 gallons or less).

#### Aerial Fallout

The State Water Resources Control Board's Basin Plan also contained estimates of pollution loads from aerial fallout. These estimated pollution loads expected to occur in precipitation falling on San Francisco Bay and aerial mass emissions due to dry fallout are presented in Table II-6.

As can be seen from the data presented in Table II-6, pollution loads discharged to the Bay from aerial fallout are insignificant relative to loadings to the Bay from other sources.

#### Dredging Spoils

Dredging by itself produces minimal water quality problems in comparison to the disposal of the dredged material. Problems associated with dredging are generally localized and of a temporary nature. Dredging can cause the temporary destruction of local benthic organisms, increases in turbidity, decreased dissolved oxygen concentrations, and increased toxicity.

The estimated waste loads shown in Table II-5 are very small when compared to those shown previously for other types of discharges. Therefore, they are probably insignificant in affecting water quality in the Bay with respect to nutrients.

#### Accidental Spills

Ship-related operational failures rather than casualty events are the main causes of accidental spills in San Francisco Bay. These include discharge of contaminated ballast and bilge water and

TABLE II-6

ESTIMATED POLLUTION LOADS  
DISCHARGED TO SAN FRANCISCO BAY  
FROM AERIAL FALLOUT  
(1,000 pounds/year)

Constituent	Rainfall	Dustfall
Nitrogen	1,300	865
Phosphorus	130	144
Copper	27	
Lead	44	577
Mercury	0.520	
Nickel	5.6	
Zinc	139	
DDT Compounds	0.130	0.580
PCB's	0.134	0.580

Source: SWRCB, 1975

There are presently five dredge spoil disposal sites in San Francisco Bay. The Corps of Engineers is conducting a detailed dredge spoil disposal study to determine the effects of dredging and disposal on the marine environment. The study will also develop dredging and disposal procedures to mitigate adverse effects on the marine resources.

#### Summary

A summary comparison of pollutant loads presently discharged to the San Francisco Bay system is presented in Table II-7.

As can be seen by reviewing the data in Table II-7, municipal and industrial wastewater discharges contribute significant amounts of BOD<sub>5</sub>, nitrogen, and phosphorus to the Bay system when compared to other sources, whereas Delta outflow contributes significant amounts of suspended solids and nitrogen compared to the other sources.

TABLE II-7

SUMMARY COMPARISON OF 1975 POLLUTANT LOADS  
DISCHARGED TO THE SAN FRANCISCO BAY SYSTEM

Pollutant Source	Flow 1,000 acre-ft	Pollutant Load, 1,000 lb/yr				
		BOD <sub>5</sub>	TSS	TN	NH <sub>3</sub> -N	TP
Municipal Wastewater	600	135,208	86,341	45,026	29,454	25,269
Industrial Wastewater	58	43,524	19,195	1,701	1,250	119
Stormwater Runoff	1,890	19,600	-	5,160	-	650
Marine Vessels	-	635	-	127	-	16
Aerial Fallout	-	-	-	2,160	-	274
Delta Outflow	18,000	47,400	3,520,000	31,400	2,150	6,500

## WATER QUALITY CHARACTERISTICS

A comprehensive investigation of San Francisco Bay was undertaken by the University of California (SERL) during the period 1960-1964. It was an extensive data collection program designed to characterize water, biological, and sediment quality, as well as waste discharges having potentially adverse effects on the Bay. A summary of the water quality characteristics observed in San Francisco Bay during the comprehensive studies is presented in Table II-8. Receiving water segments are shown on Figure II-1.

Present conditions are known to be significantly improved in some areas from those observed during the comprehensive studies. This was pointed out in the Basin Plan as follows:

"Since 1964, coliform bacterial levels throughout the Bay, and especially in the Central Bay, have been reduced as a result of a stepped-up program of disinfection (by chlorination) of sewage treatment plant effluents. Secondly, dissolved oxygen concentrations in the South Bay have increased since completion of secondary treatment facilities by the City of San Jose. Toxicity in Bay waters, especially in areas adjacent to waste discharges, appears to have increased in the past years due to chlorination, additional ammonia loads, and heavy metals. The effect of such increased stress on indigenous biota has not yet been fully evaluated."

Since the comprehensive studies, many supplemental studies and reviews of particular water quality problems in the Bay have been made. Highlights of these evaluations as reported in the Basin Plan follow:

"In South San Francisco Bay there is little freshwater inflow other than wastewater, except during heavy rainfall; evaporation from the Bay's surface waters makes this system a negative estuary during portions of the year. Flushing is sporadic at best and pollutants may be retained in the system for long periods. In the lower extremity, BOD of Bay water has been observed to be as high as 48 mg/l, essentially that of treated wastewater, while DO's have been as low as 0.7 mg/l. Such low levels of oxygen preclude survival of most fishes and many invertebrate organisms characteristically identified with a healthy aquatic habitat. Coliform bacteria counts often exceed standards for water contact recreation. The ecology of bottom habitat

TABLE II-8  
SUMMARY OF WATER QUALITY CHARACTERISTICS  
OBSERVED IN SAN FRANCISCO BAY

Parameter	Unit		South Bay	Lower Bay	Central Bay	North Bay	San Pablo Bay	Suisun Bay
Temperature	°C	low <sup>a</sup>	9.3	10.7	10.1	11.3	8.3	6.9
		mean	16.3	14.8	13.5	14.1	14.9	15.0
		high <sup>b</sup>	24.0	21.0	19.0	17.6	19.3	21.3
Secchi disc transparency	ft	low	0.5	0.5	1.0	1.3	0.5	0.5
		mean	1.9	3.5	4.6	3.9	1.6	0.9
		high	4.0	8.5	9.0	6.5	3.5	1.5
pH		low	7.2	7.8	7.6	7.5	7.2	7.4
		mean	7.6	7.95	7.9	7.85	7.65	7.65
		high	8.0	8.1	8.1	8.0	7.9	8.0
Suspended solids	mg/l	low	15	8	5	6	13	34
		mean	55	29	15	21	45	65
		high	164	56	38	57	245	112
Chlorosity	g/l	low	9.5	13.5	15.5	10	3.5	0.02
		mean	15	16	16.5	16	10.5	2.5
		high	19	17	18	18	16	8.5
Dissolved oxygen	mg/l	low	0.7	7.0	6.5	6.2	6.8	6.6
		mean	5.1	7.4	7.3	7.4	8.0	8.4
		high	8.3	8.5	8.2	8.5	9.3	10.2
Dissolved oxygen saturation	%	low	9.3	81	80	75	80	65
		mean	55	90	84	85	85	85
		high	92	99	92	96	92	94
Biochemical oxygen demand	mg/l	low	0.5	0.4	0.4	0.1	0.1	0.4
		mean	10	0.8	0.7	0.7	0.8	1.1
		high	48	1.5	1.0	1.5	1.4	2.1
Ammonia nitrogen	mg/l-N	low		0.06	0.05	0.03	0.06	0.01
		mean	3	0.12	0.15	0.13	0.15	0.13
		high	11	0.21	0.48	0.24	0.34	0.28
Nitrate nitrogen	mg/l-N	low	0.05	0.08	0.16	0.12	0.03	0.04
		mean	0.35	0.34	0.24	0.23	0.35	0.31
		high	1.1	0.55	0.36	0.38	1.0	0.95
Reactive phosphate	mg/l-P	low	-	0.10	0.07	0.07	0.07	0.03
		mean	-	0.16	0.10	0.07	0.10	0.07
		high	-	0.26	0.13	0.13	0.13	0.10
Dissolved silica	mg/l	low	2.3	2.9	1.4	2.5	1.4	1.5
		mean	8.7	5.4	3.6	4.8	6.8	13.6
		high	16	7.7	5.5	6.8	14	30
Coliform bacteria	MPN/100 ml	low	10	10	200	200	20	700
		mean	2x10 <sup>4</sup>	5x10 <sup>2</sup>	1x10 <sup>3</sup>	5x10 <sup>2</sup>	1x10 <sup>3</sup>	3x10 <sup>3</sup>
		high	3x10 <sup>8</sup>	3x10 <sup>4</sup>	6x10 <sup>4</sup>	1x10 <sup>4</sup>	1x10 <sup>4</sup>	2x10 <sup>4</sup>
Total microplankton	cells/l	low	1.2x10 <sup>3</sup>	3.0x10 <sup>3</sup>	6.6x10 <sup>3</sup>	7.0x10 <sup>3</sup>	3.0x10 <sup>3</sup>	4.6x10 <sup>4</sup>
		mean	1.4x10 <sup>4</sup>	1.0x10 <sup>4</sup>	3.7x10 <sup>4</sup>	3.2x10 <sup>4</sup>	4.7x10 <sup>4</sup>	3.6x10 <sup>5</sup>
		high	3.8x10 <sup>5</sup>	1.5x10 <sup>6</sup>	6.7x10 <sup>5</sup>	3.0x10 <sup>5</sup>	1.2x10 <sup>6</sup>	3.4x10 <sup>6</sup>
Total zooplankton	org/cu m	low	500	5,400	3,000	1,000	300	500
		mean	7,000	8,800	7,800	8,000	10,000	3,000
		high	40,000	12,000	15,000	23,000	32,000	19,000

<sup>a</sup>low = 5 percentile value.<sup>b</sup>high = 95 percentile value.

Source: SWRCB, 1975

See Figure II-1 for area locations; "South Bay" and "Lower Bay" refer to South San Francisco Bay south and north of the San Mateo Bridge, respectively.

is characterized by shifting community composition and lower diversity of organisms than found in many other segments of the Bay. Studies by the USGS and others have revealed high concentrations of toxic heavy metals such as lead, copper, mercury, cadmium, zinc, and chromium in the bottom sediments of the Bay. Pesticides and hexane extractables also appear to be accumulating thus contributing to further deterioration of the benthic environment. Waste loads contributing to this problem originate from agricultural drainage, municipal storm sewer and sanitary sewage systems, urban runoff, mines and exposed mine processing slag heaps as well as directly via aerosols. This southernmost segment of the Bay is the most severely degraded of any within the Bay-Delta system."

"Along a longitudinal traverse from South Bay toward Central Bay, the quality of the water and bottom sediment and biotic conditions gradually improve. Except for localized conditions around port facilities and points of major waste discharge, there are few indications of general environmental degradation such as occur in the extreme South Bay. Sediment quality is very poor and benthic animal populations sparse in the vicinity of major port facilities such as Hunter's Point and Alameda. Acute degradation is often associated with petroleum products and heavy metals. Discharges in wharf areas often cause serious transient problems, resulting in occasional fish kills which may be indicative of acute and chronic water quality problems."

"In the northern arm of the Bay, where large quantities of municipal and industrial wastewaters are discharged to San Pablo Bay, Carquinez Strait, and Suisun Bay, water quality was found to be much different than that in the extreme southern portion because of greater tidal flushing and positive displacement toward the ocean by freshwater inflow from the Delta. In this reach, there were several indications of degradation associated with depressed benthic diversity, localized heavy metal buildup near industrial discharges, periodic fish kills, and some eutrophication in backwater shallows."

## FISH AND WILDLIFE RESOURCES

The following discussion relative to the fish and wildlife resources of San Francisco Bay was abstracted from the State Water Resources Control Board's Water Quality Control Plan Report for the San Francisco Basin (2) dated November 1974.

The San Francisco Bay system is the most extensive and in many ways the most significant estuary on the California coast. Its deepwater channels, tidelands, marshlands, freshwater streams, and rivers provide a variety of habitats which become more critical in the preservation of several species as other estuaries have been reduced in size or lost to development. Myriads of fish and wildlife species utilize these habitats for feeding and nursery grounds. The Bay system also provides a migratory pathway for anadromous fish and is a key stopping point for migratory birds on the Pacific Coast Flyway.

The unusual physical characteristics of the Bay system contribute to the diversity of habitat within it. Deepwater areas exist within each segment of the Bay adjacent to large expanses of very shallow water. A wide salinity range from hypersaline to freshwater is nearly always present and wide ranges of water temperature are also encountered.

### Anadromous Fisheries

The anadromous fishes are commonly considered to be the most important group of fishes in the San Francisco Bay system. They include the striped bass, chinook and coho salmon, steelhead, two species of sturgeon, and American shad. These fish spend most of their lives in the open ocean but depend on freshwater streams and rivers as spawning grounds. Juvenile striped bass make extensive use of the highly productive shallow water margins of the Bay system as feeding grounds.

Adult striped bass spend the summer primarily in the Central Bay, San Pablo Bay, and the ocean. In the fall many of them migrate through San Pablo Bay, Carquinez Strait, and Suisun Bay into the Delta. Others overwinter in San Pablo or San Francisco Bay and then migrate through the Delta to spawn upstream in the Sacramento and San Joaquin Rivers during spring. Later the eggs and larvae are carried back downstream into the Delta. In summer most young-of-the-year bass inhabit Suisun Bay.

Historically, two species of salmon migrated through the Bay system in great numbers to spawn. However, most of the coho (silver) salmon runs have been eliminated and spawning of the present population is restricted to the coastal streams. Chinook (king) salmon, on the other hand, spawn or are artificially spawned in the Sacramento and San Joaquin River systems. The patterns of movement of young and adult chinook salmon through the estuary are complex because three genetically different strains migrate at various times of the year. As a result, salmon are always present somewhere in the system at a particular time of the year. Nonetheless, a peak in the rate of downstream migration of young salmon through the estuary occurs during the months of May and June.

The only salmon that actually spawn within the basin boundaries are the coho salmon. They utilize the gravel beds of clear flowing coastal streams between November and February. These fish are also returning to streams such as San Francisquito Creek and Pinole Creek where water quality has recently improved. Fry remain in the streams for a full year before returning to the ocean. Intertidal mudflats are of unknown importance to young salmonids. However, it is known that the mudflats of Suisun Bay are heavily used as feeding grounds by both salmon and steelhead trout.

The steelhead which migrate through the Bay system support a recreational fishery of approximately 58,000 angler days annually. Most of this catch, like that of coho salmon, is made in the tributary rivers and streams. The pattern and timing of migration varies among populations in different streams. Steelhead have been observed migrating in some streams at all times of the year (Messersmith, 1966). However, Messersmith observed two migratory peaks through Carquinez Strait. The largest peak occurred in April and May while a smaller peak occurred in September.

Although their migration habits are not well understood, white sturgeon are found in all of the bays and are most abundant in San Pablo and Suisun bays. Some adult fish move upstream into the lower Sacramento River in late winter and then migrate up the Sacramento during the spring to spawn. The sport fishery is small but important because of the interest generated by the large size of the sturgeon. Contrastingly, green sturgeon are less well known and less common than white sturgeon. It is believed that they enter the ocean more frequently than the white sturgeon. There is virtually no fishery for green sturgeon.

Adult American shad spend most of their lives in the ocean. They enter San Francisco Bay in the late winter and early spring and proceed upstream to spawn above the Delta; few of these fish enter the lower reaches of the Bay. The young migrate downstream the following fall, using much the same route as the adults. American shad are generally taken upstream in the Delta and in several Central Valley rivers.

#### Marine Fin Fishes and Decapods

Sole, halibut, flounder, turbot, sanddabs and other fishes belonging to either the right-eyed or left-eyed flounder family are generally classified as flat fishes. Until recently this fishery was centered at San Francisco, and both San Francisco and San Pablo bays were important fishing areas.

Starry flounders and English sole are the most abundant flatfish in the Bay system. Starry flounders are more numerous in San Pablo and Suisun bays, but both species are present throughout the remainder of the Bay. English, Dover, and petrale sole comprised the largest portion of the commercial flatfish catch between 1955 and 1968. Rex sole, sanddabs, flounder, turbot, and California halibut also contributed to the total flatfish catch for the 13-year period.

Other marine fin fish include blue rockfish, sharks, skates, rays, surf perch, and croakers. Although a small commercial fishery exist for each of these species, the demand is primarily recreational. Blue rockfish commonly occur between 40 and 50 fathoms, but also may be found in tide pools and nearshore kelp beds. Surf perch are common along beaches and alongside wharfs and pilings of the Bay. Their principal importance is that of forage for striped bass.

Most important among invertebrate organisms in the San Francisco Bay basin from a commercial standpoint is the Dungeness crab (Cancer magister). Adult crabs prefer shallow sandy bottoms outside the Golden Gate at depths ranging from 25 to 90 feet. Juveniles, on the other hand, are found throughout the northern part of San Francisco Bay as far east as Carquinez Strait. Since commercial size crabs are not generally found inside the Golden Gate, it appears that the Bay is used primarily as a nursery ground. A sizeable commercial fishery, however, exists outside the Golden Gate.

### Shrimp and Forage Fin Fishes

Three species (Crago franciscorum, C. nigricauda and C. nigromaculata) of bay shrimp are taken commercially and are found throughout the Bay. The mysid shrimp, Neomysis mercedis, has been identified as a highly important source of food for many fishes in the estuary, including the anadromous striped bass and chinook salmon. Forage fin fishes such as Pacific herring, smelts, and northern anchovy make up the majority of the food items eaten by the fishes of the Bay and thus represent the basis for a multi-million dollar resource.

### Shellfish

Both softshell and littleneck clams occur in the intertidal zone of San Francisco Bay in sufficient numbers to be considered potentially harvestable. Other clams found in much lower numbers include the gaper clam, the native littleneck clam, the bentnosed clam, the basket cockle, the Washington clam, and the quahog.

Both Eastern and Pacific oysters were once harvested commercially in the Bay and are still abundant. The native oyster is widespread but is not important commercially due to its small size and poor flesh. Ribbed horsemussels are abundant in the Lower Bay and bay mussels are common throughout.

None of these shellfish may presently be taken from San Francisco Bay for human consumption. Excessive coliform contamination has resulted in a public health quarantine. However, they are harvested both commercially and for sport purposes in Tomales Bay and Drake's Estero.

### Aquatic Birds

The San Francisco Bay system is considered essential as a wintering ground, feeding area, and nesting place on the Pacific Flyway. The Bay system provides important nesting and breeding areas for over 75 species of aquatic birds which either reside or are regular visitors to the Bay system. Most of the waterfowl using the San Francisco Bay system are ducks. Of these, 92 percent are puddle ducks, which feed on shallow water vegetation, particularly alkali bulrush. The remaining eight percent are diving ducks which feed on the invertebrate fauna of deeper waters (up to 18 feet).

In contrast, shorebirds do not generally nest or breed in the basin. Instead they are migrants or winter residents. Most reliable estimates of the average winter shorebird population fall in the range between 100,000 and 200,000 animals. Wading birds such as egrets and herons are resident species that breed at several locations in the Bay system.

### Wildlife Species

The numbers and variety of wildlife in the basin are typical for coastal California. Good populations of Columbian black-tailed deer occur throughout the Bay Area. A few mountain lions still inhabit the deer ranges.

Small upland game mammals such as the Audubon cottontail, brush rabbit, jackrabbit, and western grey squirrel are plentiful throughout the foothills and woodlands. California quail and mourning dove are the chief upland game birds of the Bay Area. Many of the common upland furbearers reside here including the coyote, gray fox, badger, skunk, opossum, weasel, bobcat, and raccoon.

Water-associated mammals abound in the marshlands and waters of the Bay. Small colonies of harbor seals inhabit Bay waters where they feed on fish and shellfish. Important hauling grounds are located at the mouths of Mowry and Newark Sloughs and Calaveras Point in South San Francisco Bay, on Castro Rocks at the east end of the Richmond-San Rafael Bridge, and on Lower Tubbs Island in San Pablo Bay. Occasionally, sea lions and harbor porpoises are also seen within the Bay. Other water-associated mammals, such as river otter, muskrat, raccoon, mink, and beaver occur in the marshlands and sloughs adjacent to Bay waters.

Many species of amphibians and reptiles occur throughout the basin. Amphibians (frogs, toads, and salamanders) require permanent freshwater habitat. Frogs additionally need shallow water where metamorphosis can occur and all amphibians require shelter and cover along the water's edge. Bullfrogs are the only amphibians possessing commercial or sport value. Other common species are the California newt, California slender salamander, western toad, western fence lizard, gopher snake, common king-snake, and several species of racers.

### Rare and Endangered Species

Several endangered animal species occur in the basin whose populations have been reduced to such low levels that doubt exists as to their potential for recovery. Species are classified rare when their numbers are so low throughout their range that they may be endangered if their environment deteriorates further. These species are afforded protection by various State and Federal wildlife agencies. Their current status is given in Table II-9.

### SEDIMENTS

As part of its Comprehensive Study of San Francisco Bay, the University of California's Sanitary Engineering Research Laboratory (SERL) analyzed the sediment quality characteristics at 51 separate stations throughout the Bay system. According to SERL's report (SWRCB, 1971), the analysis of the sediment quality data showed that with some exceptions the observed characteristics were more dependent upon the particular type of sediment than they were upon the location in the Bay. Consequently, Table II-10 presents only the minimum, median, and maximum observed values in the entire Bay system.

In describing the characteristics of the Bay sediments, SERL stated:

"Probably the single most useful parameter for characterizing the physical nature of the sediments is the percentage of sand in the sample. At the 51 stations sampled in this investigation, the mean sand content ranged from 13 to 93 percent. Except for the stations in Suisun Bay, there is little difference between the sand content of the stations in each of the other five study areas. In the Suisun Bay area the percentage of sand is higher than in the rest of the Bay."

### SUISUN MARSH

The Suisun Marsh, which encompasses 85,000 acres of leveed marshland and small waterways adjacent to Suisun, Grizzly, and Honker bays, can also be affected by varying Delta outflows. Varying outflows affect salinity conditions in the Marsh, which in turn affect the type of plants which grow there.

TABLE II-9

LIST OF RARE AND ENDANGERED SPECIES FOR  
BASIN 2 AND ADJACENT OCEAN WATERS

Common name	Scientific name	Source			
		FR	BSF&W	Cal. 1	Cal. 2
Mammals					
*Southern sea otter	<u>Enhydra lutris nereis</u>		T		
Elephant seal	<u>Mirounga angustirostris</u>		U		
Gray whale	<u>Eschrichtius glaucus</u>		T		
Humpback whale	<u>Megaptera novaeangliae</u>		T		
Salt marsh harvest mouse	<u>Reithrodontomys raviventris</u>	E	T	E	F
Sei whale	<u>Balaenoptera borealis</u>		T		
Blue whale	<u>Balaenoptera musculus</u>		T		
Finback whale	<u>Balaenoptera physalus</u>		T		
Right whale	<u>Eubalaena glacialis</u>		T		
Sperm whale	<u>Physeter catodon</u>		T		
Birds					
California brown pelican	<u>Pelecanus occidentalis</u>	E	T	E	
*Southern bald eagle	<u>Haliaeetus leucocephalus</u>	E	T	E	F
White tailed kite	<u>Elanus leucurus</u>		T		F
American osprey	<u>Pandion haliaetus carolinensis</u>		U		F
Prairie falcon	<u>Falco mexicanus</u>				
American peregrine falcon	<u>Falco peregrinus anatum</u>	E	T	E	F
*Greater sandhill crane	<u>Grus canadensis tabida</u>				F
California clapper rail	<u>Rallus longirostris obsoletus</u>	E	T	E	F
California black rail	<u>Laterallus jamaicensis coturniculus</u>		T	R	F
Western snowy plover	<u>Charidrius alexandrinus nivosus</u>		U		
Alaskan short billed dowitcher	<u>Limnodromus griseus caurinus</u>		U		
Yakutat fox sparrow	<u>Passerella iliaca annectens</u>		U		
California least tern	<u>Sterna albifrons browni</u>	E	T	E	F
California yellow-billed cuckoo	<u>Coccyzus americanus occidentalis</u>	E	T	E	F
Samuel's song sparrow	<u>Melospiza melodia samuelis</u>		U		
Suisun song sparrow	<u>Melospiza melodia maxillaris</u>		U		
San Francisco song sparrow	<u>Melospiza melodia pusilla</u>		U		
In addition, all shorebirds are protected.					
Reptiles					
Alameda striped racer	<u>Masticophis lateralis euryxanthus</u>			R	
San Francisco garter snake	<u>Thamnophis sirtalis tetrataenia</u>	E	T	E	
Giant garter snake	<u>Thamnophis couchii gigas</u>		U	R	F
Fishes					
Thicktail chub	<u>Gila crassicauda</u>			U	
Sacramento perch	<u>Archoplites interruptus</u>		U	E	
Tidewater goby	<u>Eucyclogobius newberryi</u>		U		F

FR - Federal Register, Vol. 35, Number 199, October 13, 1970.

BSF&amp;W - Bureau of Sport Fisheries and Wildlife. Threatened Wildlife of the United States. 1973.

Cal. 1 - California Department of Fish and Game. At the Crossroads: A Report on California's Endangered and Rare Fish and Wildlife. 1974.

Cal. 2 - California Department of Fish and Game. California's Fully Protected Birds, Mammals, Reptiles, Amphibians and Fish. January, 1971.

T - Threatened

E - Endangered

R - Rare

F - Fully protected

U - Status uncertain

\* - Occurrence of this species or subspecies is uncertain or questionable.

TABLE II-10

SUMMARY OF SEDIMENT QUALITY CHARACTERISTICS  
OBSERVED IN SAN FRANCISCO BAY

Parameter	Unit	Minimum	Median	Maximum
Percent Sand	%	13	46	93
Cation Exchange Capacity	meq/100 g	2.3	19.6	66.1
Bulk Density	g/ml	1.06	1.44	2.65
Moisture	%	22.6	47.6	88.6
Total Sulfide	mg/g	0	0.22	5.80
Total Nitrogen	mg/g	0.05	1.11	13.5
Total Carbon	%	0	1.27	37.0
Organic Carbon	%	0	1.10	37.0
Putrescibility Index	mg/g	0.01	1.8	11

Source: University of California Sanitary Engineering Research Laboratory

The marsh is the largest contiguous marsh in the Continental United States and serves as a principal wintering ground for migratory birds using the Pacific Coast Flyway as well as supporting a significant resident waterfowl population of as many as 20 percent of California's waterfowl during dry years. The large expanses of habitat in a relatively remote setting combined with the diverse vegetation and favorable aquatic conditions make Suisun Marsh one of the most important wildlife habitat areas in California.

Over 175 species of plants have been identified in the Marsh. Of these, at least 35 are known to be used as duck food. An estimated 202 species of birds and 26 different mammals are known to frequent the Marsh at sometime during the year. Several rare and endangered species also inhabit the Marsh. Those observed in the Marsh or its immediate environs by the California Department of Fish and Game include the American Peregrine Falcon, Prairie Falcon, Clapper Rail, Black Rail, and Samuel's Long Sparrow. Other species possibly found in the area include the Tule White-Fronted Goose, Southern Bald Eagle, and the Salt Marsh Harvest Mouse.

## REGULATORY AUTHORITY

Many Federal and State laws have been enacted which establish the requirements for adequate planning, implementation, management, and enforcement, including penalties for noncompliance, for the control of water quality. In addition, Federal regulations as well as State regulations and plans have been developed to augment and clarify the laws and to provide detail not included in the laws. Some of the more important laws and regulations are discussed later in this section.

In California the effectiveness of water quality control programs has been attributed in part to a planning and regulatory system which is flexible and responsive to regional needs as well as being innovative and demanding in regulation and enforcement. Regional agencies involved in water quality control programs, therefore, are also discussed later in this section.

### Federal Water Pollution Control Act

Public Law 92-500, known as the Federal Water Pollution Control Act Amendments of 1972, was passed by the Congress on October 18, 1972. The objective of the 1972 Amendments is to restore and preserve the integrity of the nation's waters. Six goals set forth to achieve this objective are:

1. To eliminate the discharge of pollutants to navigable waters by 1985;
2. To provide water quality which protects and fosters propagation of fish, shellfish, and wildlife and allows recreation in and on the water by 1983;
3. To prohibit discharge of toxic pollutants in toxic amounts;
4. To provide financial assistance to construct publicly-owned wastewater treatment systems;
5. To develop and implement areawide waste treatment management plans; and
6. To develop technology necessary to carry out these goals.

The 1972 Amendments are set forth in five parts or Titles which are briefly explained below.

Title I, Research and Related Programs. The goals and policies set forth above are contained in Title I. In addition, the law required the Administrator to develop, in cooperation with Federal, State, and local agencies, and industries, comprehensive programs for preventing, reducing, or eliminating pollution and improving the quality of the nation's waters.

Title II, Grants for Construction of Treatment Works. Title II provides a mechanism for development and implementation of waste treatment management plans. Implementation is to be effected by application of the best practicable waste treatment technology prior to discharge including reclaiming and recycling, and confined disposal of pollutants. Grant funds are offered to any state, interstate, or local agency for the construction of publicly-owned treatment works in the amount of 75 percent of the eligible cost of construction.

Title III, Standards and Enforcement. Title III sets forth standards for the discharge of wastewaters, provides for the establishment and Federal approval of water quality standards, requires each state to classify and rank its surface waters as to severity of pollution, and requires each state to develop a statewide planning process.

Title IV, Permits and Licenses. Title IV establishes the National Pollutant Discharge Elimination System (NPDES) permit procedure which controls discharges to navigable waters. The permit, which is required for any discharge into navigable waters, must set forth any effluent limitations, including prohibitions and monitoring requirements; standards of performance; pretreatment requirements; or any appropriate state requirement.

Title V, Administration. Title V consists of general provisions related to administration, enforcement, and other relevant aspects of the Act.

#### National Environmental Policy Act of 1969

The National Environmental Policy Act of 1969 (NEPA) directs an inter-disciplinary approach to insure integrated use of all talents in planning and decision-making having an impact on the

environment. Every report or recommendation (applicable only to actions of the Federal Government) must be accompanied by a detailed statement by the responsible official on: (1) the environmental impact of the proposed action; (2) any adverse environmental effects which cannot be avoided if the action is taken; (3) alternatives to the proposed action; (4) relationship between local short-term uses of the environment and maintenance and enhancement of long-term productivity; and (5) any irreversible and irretrievable commitments of resources if the proposed action is taken.

#### Thermal Plan

On May 18, 1972, the State Water Resources Control Board adopted a "Water Quality Control Plan for Control of Temperature in the Coastal and Interstate Waters and Enclosed Bays and Estuaries of California," referred to as the "Thermal Plan." The Plan specifies limiting conditions of temperature in wastewaters discharged into interstate and coastal waters, estuaries, and enclosed bays.

#### Enclosed Bays and Estuaries Policy

In May 1974 the State Water Resources Control Board adopted the "Water Quality Control Policy for the Enclosed Bays and Estuaries of California." The purpose of this policy is to provide water quality principles and guidelines to prevent water quality degradation and to protect the beneficial uses of such waters. With respect to San Francisco Bay, the State Board stated that waste discharges to waters of the Bay, south of the Dumbarton Bridge in South Bay, should be eliminated at the earliest practicable date.

#### State Policy for Water Quality Control

The State Water Resources Control Board has developed a set of 12 general principles to implement the provisions and intent of the Porter-Cologne Water Quality Control Act. These 12 principles are:

1. Water rights and quality control decisions must assure protection of fresh and marine waters for maximum beneficial use.
2. Wastewaters must be considered a part of the total available freshwater resource.

3. Management of supplies and wastewaters shall be on a regional basis for efficient utilization of the resource.
4. Efficient wastewater management requires a balanced program of source control of hazardous substances, treatment, reuse, and proper disposal of effluents and residuals.
5. Substances not amenable to removal in treatment plants must be prevented from entering the system.
6. Treatment systems must provide sufficient removals to protect beneficial uses and aquatic communities.
7. Sewerage facilities must be consolidated for long-range economic and water quality benefits.
8. Institutional and financial programs of consolidated systems must serve each area equitably.
9. Reclamation and reuse for maximum benefit shall be encouraged.
10. Systems must be designed and operated for maximum benefit from expended funds.
11. Control methods must be based on the latest information.
12. Monitoring programs must be provided.

More specifically, the policy provides that secondary treatment will be the minimum acceptable level of treatment and advanced treatment systems will be required where necessary to meet established water quality objectives.

#### Nondegradation Policy

The State Water Resources Control Board's Resolution No. 68-16 is commonly referred to as the "Nondegradation Policy." This policy recognizes that the quality of some waters of the State is higher than that established by adopted policies. It is the intent of the "Nondegradation Policy" that existing higher quality be maintained to the maximum extent possible.

### Basin Plan

The San Francisco Bay Basin (2) Water Quality Control Plan was adopted by the California Regional Water Quality Control Board, San Francisco Bay Region and subsequently approved by the State Water Resources Control Board on April 17, 1975. This plan contains general objectives for various water quality parameters. In addition, specific salinity objectives at Chipp's Island and in Suisun Marsh are included which are basically the same as those contained in the State Board's Decision 1379.

### California Environmental Quality Act

The California Environmental Quality Act (CEQA) is contained in Sections 21000 to 21150 of the Public Resources Code. CEQA, companion to NEPA, requires all State agencies, boards, and commissions to include, in any report on any project having a significant impact on the environment, an environmental impact report. In addition to the five items set forth in Section 102 of NEPA, CEQA requires that the report include: (1) mitigation measures proposed to minimize the significant effects; (2) growth-inducing impact of the proposed action; (3) organizations and persons consulted; (4) water quality aspects; and (5) energy considerations.

### Association of Bay Area Governments

As the areawide planning organization for the Bay Area, the Association of Bay Area Governments (ABAG) is charged with the responsibility of regional review of Federal grant applications. It is also involved in continuing areawide transportation planning, regional airport systems planning, community shelter planning, and regional criminal justice planning in addition to planning for water, sewerage, and drainage development. ABAG is presently preparing an Areawide Environmental Management Plan.

### San Francisco Bay Conservation and Development Commission

The San Francisco Bay Conservation and Development Commission (BCDC) was given three major responsibilities by the Legislature:

1. Regulation of all filling and dredging in San Francisco, San Pablo, and Suisun bays as well as all sloughs that are part of the Bay system.

2. Limited jurisdiction over substantial developments within a 100-foot strip inland from the Bay.
3. Limited jurisdiction over any proposed filling of salt ponds or managed wetlands (areas diked off from the Bay and used for salt production, duck-hunting preserves, etc.).

#### WATER QUALITY OBJECTIVES

State policy for water quality control in California is directed toward achieving the highest water quality consistent with maximum benefit to the people of the State. In keeping with this policy, all water resources must be protected from pollution and impairment that might occur as the result of waste discharge. Beneficial water uses serve as a basis for establishing water quality objectives and discharge prohibitions to achieve this goal.

#### Beneficial Uses

As part of the basin planning process, the State and Regional Water Quality Control Boards adopted a list of beneficial uses for all waters in the Basin. Table II-11 presents those beneficial uses for San Francisco Bay waters. Standard designations for beneficial uses, as defined below, are applicable throughout California.

IND (Industrial Service Supply). Includes uses that do not depend primarily on water quality such as mining, cooling water supply, hydraulic conveyance, gravel washing, fire protection, and oil-well re-pressurization.

PROC (Industrial Process Supply). Includes process water supply and all uses related to the manufacturing of products.

NAV (Navigation). Includes commercial and naval shipping.

REC 1 (Water Contact Recreation). Includes all recreational uses involving actual body contact with water such as swimming, wading, water skiing, skin diving, surfing, sport fishing, uses in therapeutic spas, and other uses where ingestion of water is reasonably possible.

TABLE II-11

## EXISTING AND POTENTIAL BENEFICIAL USES OF SAN FRANCISCO BAY WATERS

	IND	PROC	NAV	REC 1	REC 2	COMM	WARM	BIOL	WILD	RARE	MAR	MIGR	SPWN	SHELL
South Bay	●		●	●	●			●	●	●	●	●	○	●
Lower Bay	●		●	●	●	●		○	●	●	●	●	○	●
Central Bay	●	●	●	●	●	●		○	●	●	●	●	●	●
San Pablo Bay	●		●	●	●	●		○	●	●	●	●	●	●
Suisun Bay and Lower San Joaquin	●	●	●	●	●	●		○	●	●	●	●	●	●
Delta	●	●	●	●	●	●	●	○	●	●	●	●	○	●

Source: SWRCB, 1975

● Existing

○ Potential

REC 2 (Noncontact Water Recreation). Recreational uses that involve the presence of water but do not require contact with water such as picnicking, sunbathing, hiking, beachcombing, camping, pleasure boating, tidepool and marine life study, hunting, and aesthetic enjoyment in conjunction with the above activities as well as sightseeing.

COMM (Ocean Commercial and Sport Fishing). The commercial collection of various types of fish and shellfish, including those taken for bait purposes, and sport fishing in oceans, bays, estuaries, and similar nonfreshwater areas.

WARM (Warm Freshwater Habitat). Provides a warm water habitat to sustain aquatic resources associated with a warm water environment.

BIOL (Preservation of Areas of Special Biological Significance). Areas of Special Biological Significance (ASBS) are those areas designated by the State Water Resources Control Board as requiring protection of species or biological communities to the extent that alteration of natural water quality does not occur.

WILD (Wildlife Habitat). Provides a water supply and vegetative habitat for the maintenance of a wildlife habitat.

RARE (Preservation of Rare and Endangered Species). Provides an aquatic habitat necessary, at least in part, for the survival of certain species established as being rare and endangered species.

MAR (Marine Habitat). Provides for the preservation of the marine ecosystem including the propagation and sustenance of fish, shellfish, marine mammals, waterfowl, and vegetation such as kelp.

MIGR (Fish Migration). Provides a migration route and temporary aquatic environment for anadromous or other fish species.

SPWN (Fish Spawning). Provides a high quality aquatic habitat especially suitable for fish spawning.

SHELL (Shellfish Harvesting). The collection of shellfish such as clams, oysters, abalone, shrimp, crab, and lobster for either commercial or sport purposes.

## Water Quality

Water quality objectives for San Francisco Bay are designed to protect the waters for the beneficial uses presented in Table II-11. However, where existing water quality exceeds that quality necessary to protect the designated beneficial uses, existing quality guided the selection of values for constituent concentrations or properties. This approach was considered consistent with the State's "Nondegradation Policy" which states:

"...whenever the existing quality of water is better than the quality established in policies as of the date on which such policies become effective, such existing high quality will be maintained until it has been demonstrated to the State that any change will be consistent with the maximum benefit to the people of the State, will not unreasonably affect present and anticipated beneficial use of such water, and will not result in water quality less than that prescribed in the policies."

The following water quality objectives are recommended for the protection of beneficial use and aesthetic enjoyment of all surface waters inland from the Golden Gate. Both the State Board's "Thermal Plan," which sets forth objectives for temperature in surface waters of the State, and "Water Quality Control Policy for Enclosed Bays and Estuaries of California" are applicable to all surface waters inland from the Golden Gate in the Bay basin.

Odor. Waters shall be free of coloration that causes nuisance or adversely affects beneficial uses.

Tastes and Odors. Waters shall not contain taste- or odor-producing substances in concentrations that impart undesirable tastes or odors to fish flesh or other edible products of aquatic origin, or that cause nuisance or adversely affect beneficial uses.

Floating Material. Waters shall not contain floating material in concentrations that cause nuisance or adversely affect beneficial uses.

Suspended Material. Waters shall not contain suspended material in concentrations that cause nuisance or adversely affect beneficial uses.

Settleable Material. Waters shall not contain substances in concentrations that result in the deposition of material that cause nuisance or adversely affect beneficial uses.

Oil and Grease. Waters shall not contain oils, greases, waxes or other materials in concentrations that result in a visible film or coating on the surface of the water or on objects in the water, that cause nuisance, or that otherwise adversely affect beneficial uses.

Biostimulatory Substances. Waters shall not contain bio-stimulatory substances in concentrations that promote aquatic growths to the extent that such growths cause nuisance or adversely affect beneficial uses.

Sediment. The suspended sediment load and suspended sediment discharge rate of surface waters shall not be altered in such a manner as to cause nuisance or adversely affect beneficial uses.

Turbidity. Waters shall be free of changes in turbidity that cause nuisance or adversely affect beneficial uses. Increases from normal background light penetration or turbidity relatable to waste discharge shall not be greater than 10 percent in areas of 10 JTU or more; waters of characteristically low natural turbidity shall be maintained so that discharges do not cause visible, aesthetically undesirable contrast with the natural appearance of the water.

pH. The pH shall not be depressed below 6.5 nor raised above 8.5. Changes in normal ambient pH levels shall not exceed 0.2 units in waters with designated marine (MAR) beneficial uses nor 0.5 units in fresh waters with designated COLD or WARM beneficial uses.

Dissolved Oxygen. For all tidal waters, the following objectives shall apply:

In the Bay downstream of Carquinez Bridge	5.0 mg/l minimum
Upstream from Carquinez Bridge	7.0 mg/l minimum

For nontidal waters, the following objectives shall apply:

Waters designated as cold water habitat	7.0 mg/l minimum
Waters designated as warm water habitat	5.0 mg/l minimum

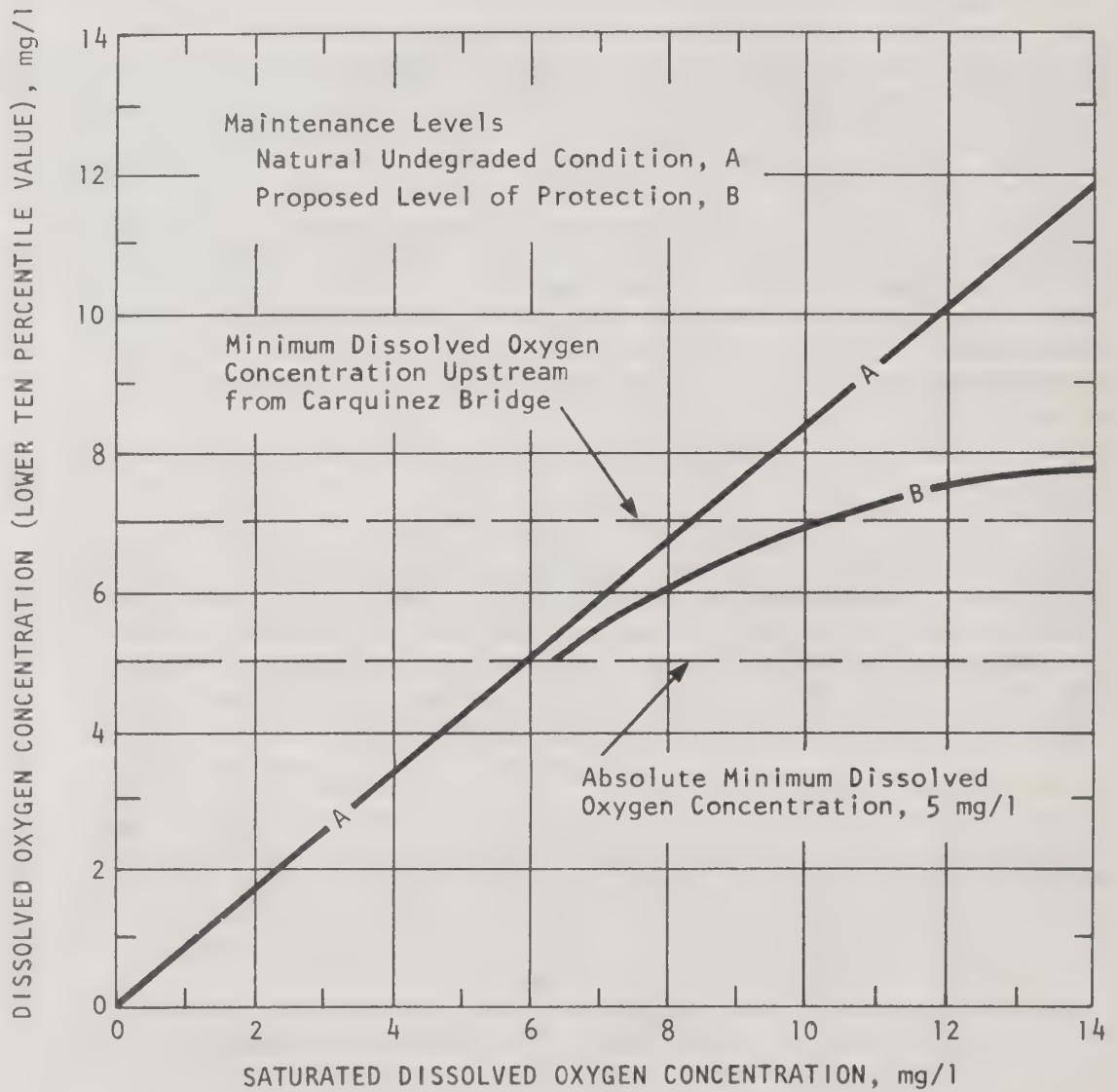
Areas of Special Biological Significance shall be maintained at a level of protection consistent with natural undegraded conditions uninfluenced by any controllable water quality factor. Where natural factors cause lower concentrations, controllable water quality factors shall not cause further reduction. All waters designated as aquatic life habitat shall be maintained at Maintenance Level B as shown on Figure II-3, unless otherwise designated. In addition to these limiting numerical objectives, the lower ten percentile dissolved oxygen concentration value shall be determined as a function of dissolved oxygen content at saturation, in accordance with Figure II-3.

Bacteria. In tidal waters designated for contact recreation, the total coliform concentration, based on a minimum of not less than five consecutive samples, shall not exceed a median value of 240/100 ml, nor shall any sample exceed a total coliform concentration of 10,000/100 ml. In addition, the fecal coliform concentration, based on a minimum of five consecutive samples, shall not exceed a median value of 50/100 ml, nor shall any sample exceed a maximum fecal coliform concentration of 400/100 ml.

At all areas where shellfish may be harvested for human consumption (SHELL), the median total coliform concentration throughout the water column for any 30-day period shall not exceed 70/100 ml nor shall more than 10 percent of the samples collected during any 30-day period exceed 230/100 ml for a five-tube decimal dilution test or 330/100 ml when a three-tube decimal dilution test is used.

In nontidal waters designated for contact recreation, the fecal coliform concentration based on a minimum of not less than five samples for any 30-day period, shall not exceed a log mean of 200/100 ml, nor shall more than 10 percent of total samples during any 30-day period exceed 400/100 ml.

In nontidal waters designated for noncontact recreation and not designated for contact recreation, the average fecal coliform concentration for any 30-day period, shall not exceed 2,000/100 ml nor shall more than 10 percent of samples collected during any 30-day period exceed 4,000/100 ml.



Source: SWRCB, 1975

LOWER TEN PERCENTILE  
DISSOLVED OXYGEN CONCENTRATIONS FOR  
WATERS DESIGNATED AS AQUATIC LIFE HABITAT  
JBGA/RIB/RTC 10/78

FIGURE 11-3

Temperature. Temperature objectives are as specified in the "Water Quality Control Plan for Control of Temperature in the Coastal and Interstate Waters and Enclosed Bays of California" including any revisions thereto. For enclosed bays, all elevated temperature waste discharges shall comply with limitations necessary to assure protection of beneficial uses. In addition, discharges established since the adoption of this temperature control plan shall not have a maximum temperature exceeding the natural temperature of the receiving water by more than 20°F, except that no new discharge of cooling water or industrial process water shall have a maximum temperature more than 4°F above the natural temperature of the receiving water.

For estuaries such as the Sacramento-San Joaquin Delta downstream to the Carquinez Bridge, all existing and future discharges must conform to the following:

1. The maximum temperature shall not exceed the natural receiving water temperature by more than 20°F.
2. Elevated temperature waste discharges either individually or combined with other discharges shall not create a zone, defined by water temperatures of more than 1°F above natural receiving water temperature, which exceeds 25 percent of the cross-sectional area of a main river channel at any point.
3. No discharge shall cause a surface water temperature rise greater than 4°F above the natural temperature of the receiving waters at any time or place.
4. Additional limitations shall be imposed when necessary to assure protection of beneficial uses.

In addition, existing cooling water and industrial process water discharges shall not have a maximum temperature exceeding 86°F, and future cooling water or industrial process water discharges having a maximum temperature greater than 4°F above the natural temperature of the receiving water are prohibited.

Toxicity. All waters shall be maintained free of toxic substances in concentrations that are toxic to, or that produce detrimental physiological responses in human, plant, animal, or aquatic life. Compliance with this objective will be determined by use of indicator organisms, analyses of species diversity, population density, growth anomalies, bio-assays of appropriate duration or other appropriate methods as specified by the Regional Board.

The survival of aquatic life in surface waters subjected to a waste discharge or other controllable water quality factors, shall not be less than that for the same water body in areas unaffected by the waste discharge or, when necessary, for other control water that is consistent with the requirements for "experimental water" as described in Standard Methods for the Examination of Water and Wastewater, latest edition. As a minimum, compliance with this objective as stated in the previous sentence shall be evaluated with a 96-hour bioassay.

Ammonia. The discharge of wastes shall not cause receiving waters to contain concentrations of un-ionized ammonia in excess of 0.025 mg/l as N, as an annual median, and 0.4 mg/l as N, as a maximum.

Pesticides. No individual pesticide or combination of pesticides shall be present in concentrations that adversely affect beneficial uses. There shall be no increase in pesticide concentrations found in bottom sediments or aquatic life.

Sulfide. All waters shall be free from dissolved sulfide concentrations above natural background levels.

Chemical Constituents. A mean daily chloride concentration of 4,000 mg/l or less shall be maintained in waters east of the Westerly end of Chipps Island.

A mean monthly salinity at high tide of 18,000 mg/l TDS or less shall be maintained in the waters surrounding and adjacent to Suisun Marsh.

The quantity and quality of water in the bays and intertidal sloughs of Suisun Marsh shall be sufficient to produce an average salinity of 9,000 mg/l TDS in the first 12 inches of soil between April 15 and June 1 of each year.

Radioactivity. Radionuclides shall not be present in concentrations that are deleterious to human, plant, animal, or aquatic life nor that result in the accumulation of radionuclides in the food web to an extent that presents a hazard to human, plant, animal, or aquatic life.

### Nondegradation Objectives

The policy enumerated in the State Water Resources Control Board Resolution 68-16, "Statement of Policy With Respect to Maintaining High Quality Waters in California," shall apply to all waters of the State within the basin.

### Effluent Limits

Proposed effluent limits for discharges from publicly-owned treatment works, published by the Environmental Protection Agency in the Federal Register (40 CFR-133) on August 7, 1973, effectively define secondary treatment. These limits, which are required by 1977, are:

1. Biochemical oxygen demand (5-day) shall not exceed 30 mg/l as a monthly average and 45 mg/l as a weekly average.
2. Suspended solids shall not exceed 30 mg/l as a monthly average and 45 mg/l as a weekly average.
3. Fecal coliform bacteria density shall not exceed 200 MPN/100 ml as a monthly geometric mean and 400 MPN/100 ml as a weekly geometric mean.
4. pH shall be within the range of 6.0 to 9.0.

These limits may be modified where difficult industrial wastes are present which warrant revision of effluent values, particularly BOD and suspended solids; nonetheless, 85 percent removal of these two parameters will be required.

Recent Federal policy regarding Best Practicable Treatment technology (BPT) for municipal wastewater facilities was expressed in a preliminary report published by the Environmental Protection Agency on March 25, 1974. The preliminary report on BPT for

sewage does not establish specific standards but merely emphasizes that municipalities requesting Federal funds must assess all possible alternatives and select the most cost-effective method for its needs.

In addition to effluent limitations established by the Environmental Protection Agency for secondary treatment, specific limitations for the disposal of treated point-source wastes are included as part of the Basin Plan. These additional effluent limitations pertain to toxicity in both deep and shallow water discharges, coliform bacteria, residual chlorine, restriction regarding the uses for reclaimed wastewaters, and other limits which may be included as part of waste discharge permits required under the National Pollutant Discharge Elimination System.

Toxicity. Toxicity controls on effluents will be forthcoming from the Environmental Protection Agency pursuant to Section 307 of the Federal Water Pollution Control Act Amendments of 1972. Presently under consideration is a list of toxicants, which include mercury, cadmium, cyanide, polychlorinated biphenyl, and a list of pesticides, including DDT, DDE, DDD, and toxaphene. Most of these materials are cumulative poisons which can biomagnify in the food chain. Although specific effluent limits have not been established, it is expected that limits will be adopted upon completion of public hearings being conducted on this subject later this year.

Deepwater Discharges. The survival of test fishes in 96-hour bioassays of the effluent shall have a 90 percentile value of not less than 50 percent survival. Pursuant to public hearing, the Regional Water Quality Control Board may grant a revised toxicity limitation to a discharger who can demonstrate to the satisfaction of the Board that the following conditions are met: (1) the waste is discharged through a deepwater outfall which achieves rapid and high initial dilution and that the waste is rapidly rendered nonacutely toxic upon discharge, and (2) the toxicants in the waste are non-conservative constituents which are rapidly decayed in the receiving water, or the toxicants in the waste are conservative toxicants for which water quality objectives have been established. In such cases, the Regional Board will establish mass emission rates for such constituents.

Shallow Water Discharges. The survival of test fishes in 96-hour bioassays of the undiluted effluent shall achieve a median of 90 percent survival and a 90 percentile value of not less than 70 percent survival.

Coliform Bacteria. No waste discharge wherein effluent volumes comprise 10 percent or more of the receiving water volume (exclusive of previously discharged effluent) at point of access shall exceed a most probable number of coliform organisms of 2.2 per 100 ml.

Residual Chlorine. Wastewaters shall not contain residual chlorine upon discharge; it is recommended that control of chlorine removal be based on maintenance of minimal SO<sub>2</sub> residual or equivalent techniques to avoid overdosing of chemicals used in chlorine removal.

Wastewater Reuse. Reclamation of wastewater for reuse must include treatment sufficient to achieve those quality limits prescribed in Title 17, Chapter 5, Subchapter 1, Group 12, California Administrative Code, for the use intended. This section of the Administrative Code, recently revised by the State Department of Health, is a formal expression of the Department's position regarding reclaimed water uses involving ingestion. It is believed that stable organics may constitute a serious health problem where reclaimed wastewaters are used to augment domestic water supplies, and consequently projects contemplating such use will not be approved by the Department of Health until the effects of stable organics on the beneficial use are documented.

Other uses for reclaimed wastewaters are not faced with such severe restrictions. Either sewerage agencies or local water or irrigation districts could provide the increment of treatment necessary under Title 17 to allow unrestricted use of effluents on land without unusual controls on irrigation practices or crop selection. In some areas the increment of treatment may be more economic than water importation or continued reliance on poorer quality groundwaters. Under such an arrangement an effluent requirement would be that biological oxidation and filtration be provided and that a coliform limit of 2.2 MPN/100 ml be met somewhere within the treatment process. Other less stringent requirements are provided in Title 17 for fodder, fiber, and seed-crop use, wherein filtration would be waived but disinfection would be more stringent than the Federal effluent requirement.

### Waste Discharge Permits

The State of California program for issuing waste discharge permits under the National Pollutant Discharge Elimination System has been approved by the Environmental Protection Agency giving California responsibility for establishing effluent limitations for all permit applicants. Effluent limitations established by the State are reviewed by the Environmental Protection Agency, which retains veto authority over the State permit program.

In addition to effluent limits established for municipal treatment facilities, the Environmental Protection Agency has promulgated specific effluent limitations for existing industrial waste discharges together with standards of performance and pretreatment standards for new sources pursuant to Sections 304(b), 306(b) and 307(b) of the Federal Water Pollution Control Act Amendments of 1972.

In most cases the effluent limits contained in the industrial standards are performance standards based on normal practice in each industrial category. Nevertheless, best practicable treatment guidelines may require significant changes in effluent disposal practices for many existing industrial establishments.

## CHAPTER III

### SACRAMENTO-SAN JOAQUIN DELTA

The Sacramento-San Joaquin Delta, which encompasses about 738,000 acres, is located at the confluence of the Sacramento and San Joaquin rivers, as shown on Figure III-1. These two streams are the principal drainage features of the 450-mile long Central Valley, as shown on Figure III-2; consequently, Central Valley runoff flows through the Delta prior to passing through Carquinez Strait and the San Francisco Bay system on its course to the Pacific Ocean.

#### LAND RESOURCES

In its natural environment, about 125 years ago, the Sacramento-San Joaquin Delta consisted of tidal swamp and overflow lands and grasslands covered with dense growths of tules and other water-loving vegetation. It was subject to intermittent salinity intrusion during the dry summer months of below normal water years and to uncontrolled flooding during winter and spring.

Over the years, the former swamplands of the Delta have been transformed into some 50 man-made reclaimed islands and tracts largely devoted to farming. Reclamation began in earnest shortly after passage of the Arkansas or Swamp Land Act of September 28, 1850. This Act provided for a transfer of swamp and overflow lands, such as the Delta, from Federal to State ownership.

Subsequently, the California Legislature set the machinery in motion to sell these lands to private interests. However, not much interest was generated until 1868 when the 640-acre limitation attached to the original legislation was eliminated. Reclamation, to be effective, had to uncover an entire island, and this repeal brought in land speculators with the necessary capital. Within three years, almost all of the swamp and overflow land was sold, and by 1930 all swamp and overflow land considered feasible for reclamation had been leveed and was being farmed. A summary of lands reclaimed by decade is presented in Table III-1.

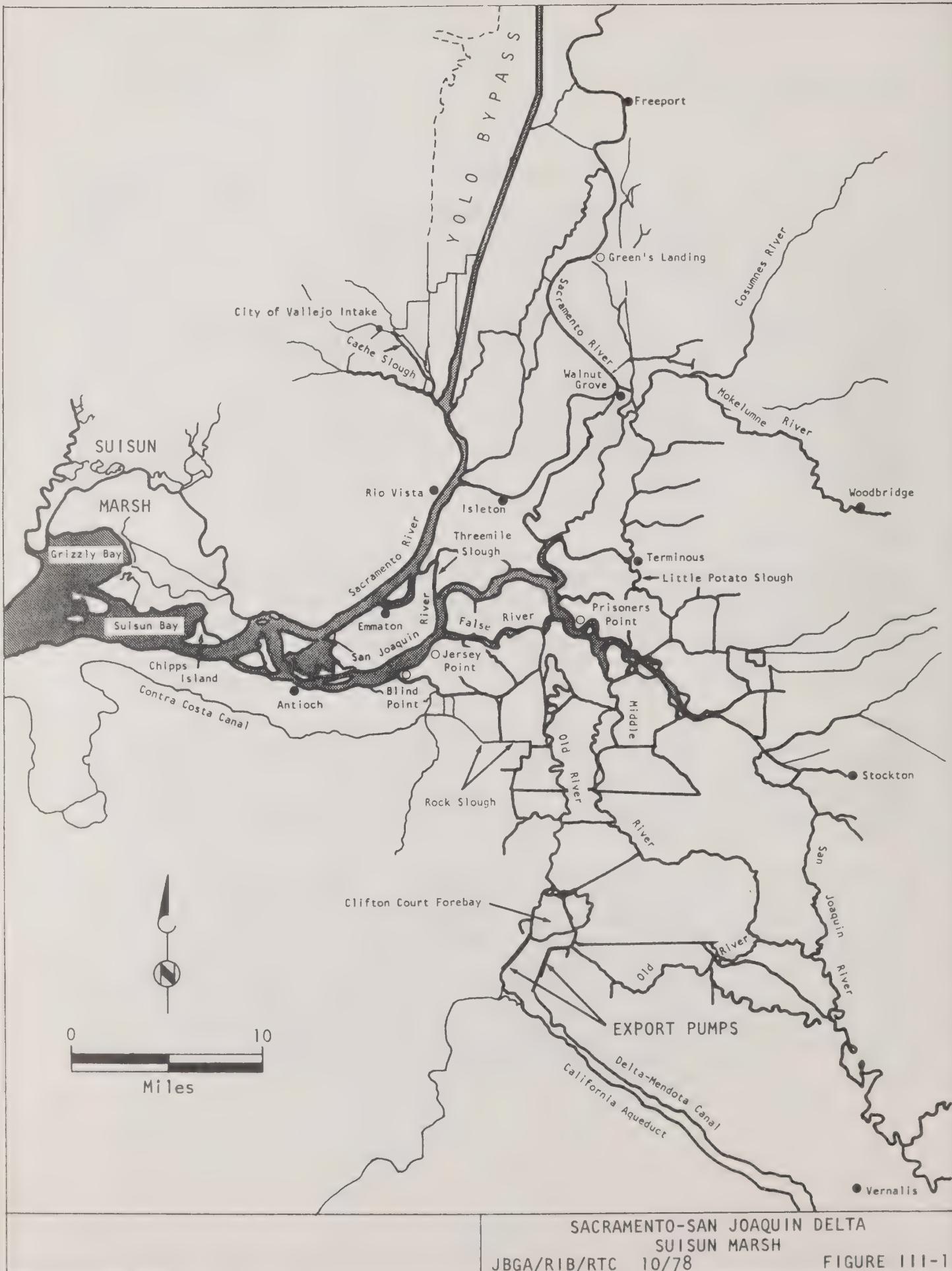
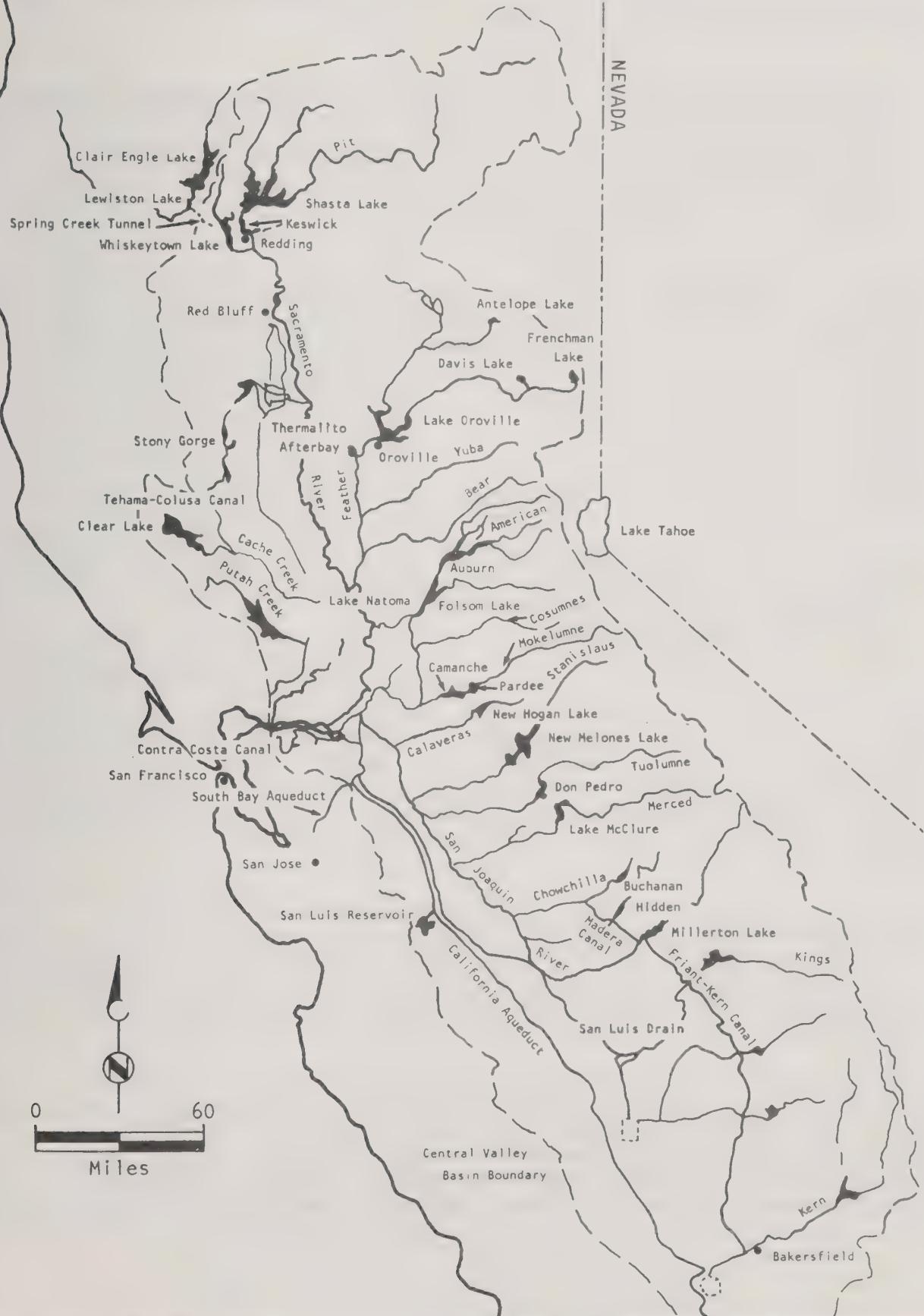


FIGURE 111-1

OREGON  
CALIFORNIA

NEVADA



CENTRAL VALLEY DRAINAGE AND WATER  
STORAGE AND EXPORT FACILITIES  
JBGA/RIB/RTC 10/78

FIGURE III-2

TABLE III-1

## RECLAMATION BY DECADE IN THE SACRAMENTO-SAN JOAQUIN DELTA

Decade	Acres Reclaimed	Accumulative Acres Reclaimed
1860-1870	15,000	15,000
1870-1880	92,000	107,000
1880-1890	70,000	177,000
1890-1900	58,000	235,000
1900-1910	88,600	323,600
1910-1920	94,000	417,600
1920-1930	24,000	441,600

Source: Department of Public Works,  
Variation and Control of Salinity  
in Sacramento-San Joaquin Delta  
and Upper San Francisco Bay,  
 Bulletin No. 27, 1931.

With an annual harvest valued at over \$140 million, agriculture is the dominant economic activity in the Delta. Productive organic soils, an unlimited supply of water, and water transportation were all positive factors that outweighed the negative factors of reclamation and subsequent restoration after major floods. As previously stated, for reclamation to be successful, entire islands or tracts had to be reclaimed with large expensive levees. This large expense ruled out the "family farm" in the Delta; as a result, much of the land is owned by corporations.

Residences are scattered throughout the Delta; and most growers commute from peripheral communities such as Rio Vista, Stockton, Tracy, and Antioch. Communities are noticeably absent from the Delta. The few towns exist because of their advantageous location as trade and transportation centers. For example, Walnut Grove is located at the head of Andrus, Tyler, and Staten Islands, whereas Isleton once functioned as a packing center.

Close to the populous San Francisco Bay Area, as well as Sacramento and Stockton, the Delta provides three million recreation days annually. San Joaquin County recreationists register the most recreation days in the area; but residents of Alameda, Santa Clara, and San Mateo counties collectively account for about one million recreation days annually.

The Delta area is flat with most of the low lands ranging in elevation from five feet above sea level to 20 feet below sea level. With some exception, the communities and most of the orchards are located above the five-foot contour. Most of the farms are below the five-foot contour, walled off from their adjacent river channels by more than a thousand miles of levees.

The more than 700-mile network of channels which separates the islands in the Delta is of great importance. Not only do they serve as water supply conduits for agriculture and other uses, they also serve as important habitat and migration routes for fish and other aquatic life, as waterways for commercial shipping and recreational boating, and as avenues for the passage of flood waters.

The upland areas, particularly in the Western Delta, i.e., Antioch and Pittsburg, have undergone steady industrialization and urbanization. This is also true for other cities around the Delta such as Sacramento, Stockton, and Tracy.

#### TRIBUTARY FLOW SOURCES

Inflow to the Sacramento-San Joaquin Delta is generally divided into three major groups by the water planning agencies: (1) the Sacramento Valley, (2) the San Joaquin Valley, and (3) Eastside Streams. Brief descriptions of these major stream groupings are presented in the following sections.

##### Sacramento Valley Inflow

The Sacramento Valley inflow includes the Sacramento River flow as measured at Sacramento and the Yolo Bypass which includes flood overflow from the Sacramento River weirs and the inflow from Knights Landing Ridge Cut, Cache Creek, Putah Creek, and other minor creeks on the southwest side of the Sacramento Valley.

##### San Joaquin Valley Inflow

The San Joaquin Valley inflow to the Delta consists almost entirely of the San Joaquin River flow as measured at Vernalis which includes flows from the Merced, Tuolumne, and Stanislaus rivers. However, minor amounts also enter the Delta directly from its southwest side.

##### Eastside Streams Inflow

The Eastside Streams Group are often subdivided into two groups: (1) the Mokelumne Group consisting of the streams from Morrison Creek south to the Mokelumne River including the Cosumnes River and Dry Creek and (2) the Calaveras Group consisting of the

Calaveras River and other minor streams from Bear Creek to French Camp Slough south of Stockton. This group of flows comprise only five percent of the total Delta inflow.

#### Summary of Delta Tributary Flows

Published data for flows from the Sacramento Valley, San Joaquin Valley, and Eastside Streams are presented in Table III-2. The 50-year mean total tributary inflow is 22,915,000 acre-feet per year. Historically, 80.0 percent of the tributary flow has come from the Sacramento Valley, 14.6 percent from the San Joaquin Valley, and 5.4 percent from Eastside Streams. The total tributary flow is shown graphically on Figure III-3, expressed as an average annual flow rate. Additional unpublished data was obtained from DWR for Figure III-3 to extend the record to 1975-1976.

#### WATER EXPORTATIONS

Water exports were first considered in 1873 when Congress instructed Lieutenant Colonel B. S. Alexander and two other engineers to examine and report on an irrigation scheme for the Sacramento, San Joaquin, and Tulare valleys. The "Alexander Survey" resulted in a report which proposed a system of canals for irrigating the Central Valley. However, in that same report, Alexander suggested that the State was not ready for such a plan.

Subsequently, on March 16, 1919, Colonel Robert Bradford Marshall, retired U. S. Geological Survey surveyor, proposed a comprehensive water resources development plan to the Governor of California. Marshall's plan was formulated on a series of basin exchanges from the water-surplus north to the water-deficient south. In 1921, Colonel Marshall took his plan and campaign to the California Assembly. Although he was damned and called crazy, he emerged with a \$200,000 appropriation for the State engineers to investigate his plan. For his efforts, Colonel Marshall has been called the "Father of the Central Valley Project."

Further investigation of the State's water needs and resources resulted, in 1930, in the comprehensive State Water Plan. This was a coordinated multipurpose plan to transfer surplus northern waters southward to areas of projected deficiency in the Central Valley. The initial units of this plan, known as the Central Valley Project, were designated by the State, authorized by the

## Sacramento-San Joaquin Delta

TABLE III-2

SACRAMENTO-SAN JOAQUIN DELTA  
ESTIMATED HISTORIC TRIBUTARY FLOWS  
(1,000 acre-feet)

Water Year	Sacramento Valley	San Joaquin Valley	Eastside Streams	Total
1921-22	17,599	7,180	1,958	26,737
1922-23	13,942	3,984	1,629	19,555
1923-24	4,908	846	222	5,976
1924-25	17,534	3,466	1,627	22,627
1925-26	12,591	2,032	700	15,323
1926-27	27,672	3,979	1,793	33,444
1927-28	18,295	2,887	1,233	22,415
1928-29	8,047	1,210	412	9,669
1929-30	14,110	1,269	519	15,898
1930-31	5,118	677	159	5,954
1931-32	12,653	3,664	1,087	17,404
1932-33	7,797	1,376	429	9,602
1933-34	8,223	928	519	9,670
1934-35	18,734	4,034	1,193	23,961
1935-36	19,442	5,000	2,118	26,560
1936-37	14,775	5,493	1,698	21,966
1937-38	39,873	10,861	2,782	53,516
1938-39	7,068	1,708	458	9,234
1939-40	26,484	4,776	1,632	32,892
1940-41	35,802	7,306	1,528	44,636
1941-42	29,465	6,167	1,990	37,622
1942-43	22,407	6,073	2,557	31,037
1943-44	9,371	1,808	648	11,827
1944-45	13,901	4,428	1,368	19,697
1945-46	18,366	3,636	1,254	23,256
1946-47	10,131	1,336	381	11,848
1947-48	15,683	1,555	743	17,981
1948-49	12,307	1,249	714	14,270
1949-50	14,358	1,789	1,025	17,172
1950-51	26,063	4,753	2,666	33,482
1951-52	32,682	7,162	2,865	42,709
1952-53	21,380	1,893	801	24,074
1953-54	18,399	1,717	629	20,745
1954-55	10,792	976	607	12,375
1955-56	33,268	6,320	2,572	42,160
1956-57	13,985	1,443	726	16,154

TABLE III-2  
(Continued)SACRAMENTO-SAN JOAQUIN DELTA  
ESTIMATED HISTORIC TRIBUTARY FLOWS  
(1,000 acre-feet)

Water Year	Sacramento Valley	San Joaquin Valley	Eastside Streams	Total
1957-58	35,574	6,077	2,624	44,275
1958-59	12,598	1,244	386	14,228
1959-60	11,348	551	279	12,178
1960-61	11,562	437	113	12,112
1961-62	14,068	1,490	706	16,264
1962-63	24,411	2,825	1,401	28,637
1963-64	11,708	1,126	325	13,159
1964-65	26,259	3,806	1,773	31,838
1965-66	13,776	1,697	658	16,131
1966-67				35,232
1967-68				15,993
1968-69				42,024
1969-70				33,248
1970-71				26,956
50-yr Mean				22,915

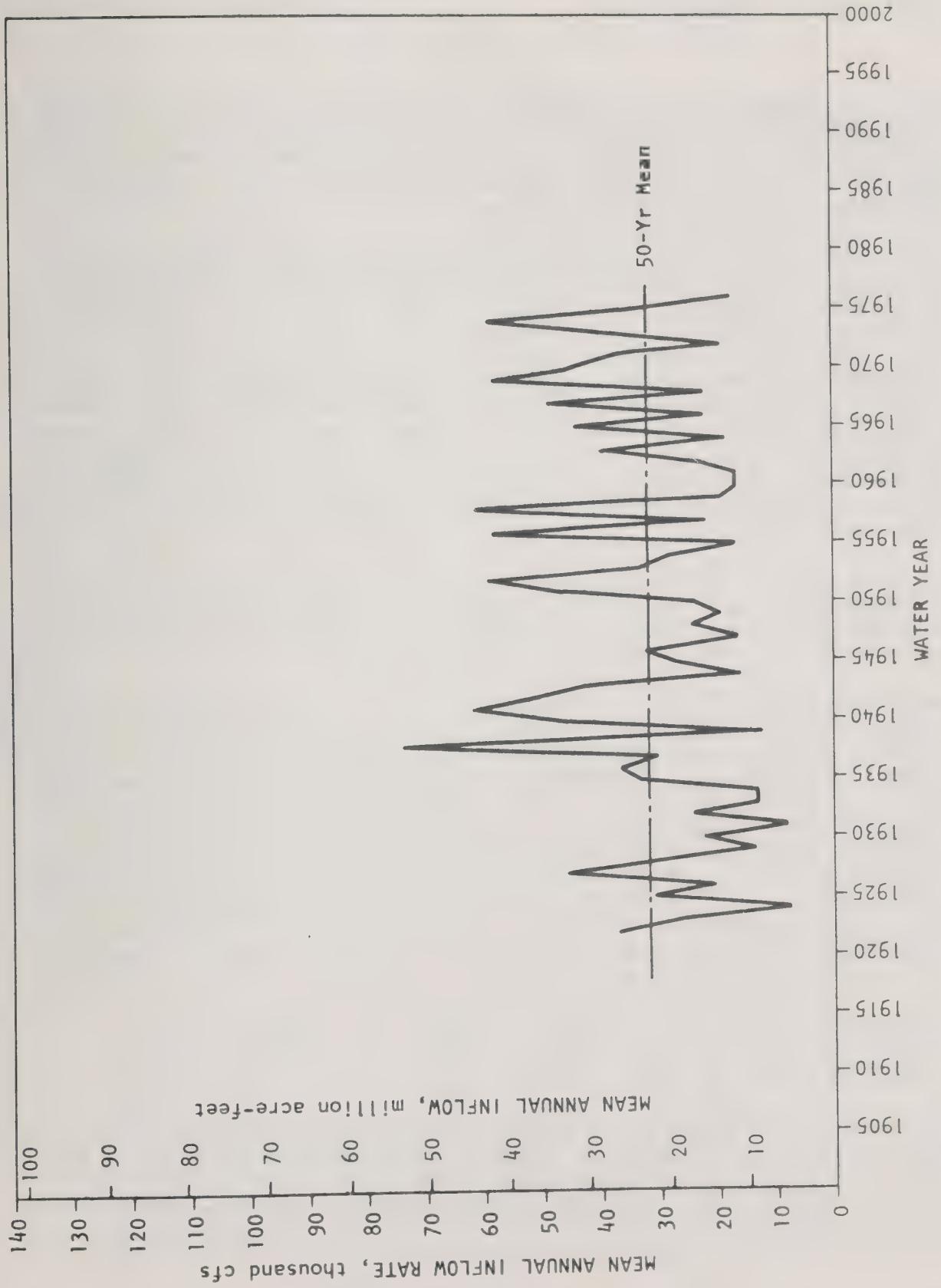
Source: California Department of Water Resources Memorandum, Estimates of Delta Water Supply and Disposal, December 16, 1971 and March 21, 1977

Legislature, and approved by the voters in 1933. Although the depression prevented the sale of the necessary revenue bonds, the legislation has remained in effect and is the substance for construction and operation of the State Water Project.

Brief descriptions of the ensuing Federal Central Valley Project and State Water Project follows. Facilities are shown on Figure III-2.

#### Federal Central Valley Project

The Federal Central Valley Project, an outgrowth of the State Water Plan approved by the California voters in 1933, was authorized by the Federal Government in 1935 and undertaken by



ESTIMATED ANNUAL HISTORIC DELTA INFLOW  
FROM ENTIRE CENTRAL VALLEY  
JBGA/DLF/RTC 9/77

FIGURE 111-3

the U. S. Bureau of Reclamation. This project has been developed to transfer water from the Sacramento and Trinity basins, where surpluses exist, to serve areas of the Sacramento and San Joaquin valleys. The service area encompasses 28 counties and is about 400 miles long and 45 miles wide.

The key unit of the Central Valley Project is Shasta Dam and Reservoir on the Sacramento River. Water stored there is used for power generation and released into the natural channels for irrigation during the dry season. Keswick Dam and Power Plant, nine miles downstream from Shasta, has a fish elevator which salvages upstream migrating salmon and trout before they reach Shasta Dam. Keswick Reservoir is augmented by additional water brought through the Spring Creek Tunnel from the Trinity River. Folsom and Nimbus dams on the American River also store water for release into the Sacramento River upstream of the Delta. A listing of the Central Valley Project storage facilities is shown in Table III-3.

Thirty miles south of Sacramento, the Delta Cross Channel helps to provide for the regulated passage of Sacramento River water through the Delta channels to the pumping plants of the Delta-Mendota Canal and Contra Costa Canal.

The Delta-Mendota Canal delivers water 117 miles south to the San Joaquin River where it replaces the natural flows of the River. However, these replacement flows are also diverted for irrigation so that only a small percentage of the original San Joaquin River flows now enter the Delta. This occurs because the natural San Joaquin River flows are stored by Friant Dam and Millerton Reservoir in the Sierra Nevada foothills northeast of Fresno at which point water is distributed to the north and south by the Madera and Friant-Kern Canals. The Friant-Kern Canal carries water south about 150 miles to near Bakersfield. The Madera Canal carries water about 30 miles northwest. Friant Dam and associated canals are also units of the Central Valley Project.

The Contra Costa Canal extends 48 miles from the Delta to provide water for industries and municipalities in portions of Contra Costa County.

San Luis Dam and Reservoir and its associated pumping, generating, and storage facilities are located about 60 miles south of the Delta and are joint-use facilities of both the Federal Central Valley Project and the State Water Project. Water diverted from the Delta is pumped into San Luis Reservoir during the winter and early spring for release to service areas during the summer and

TABLE III-3  
CENTRAL VALLEY PROJECT STORAGE FACILITIES

Storage Reservoir	Stream	Capacity (1,000 acre-feet)	First Year of Operation
Shasta Lake	Sacramento River	4,552	1944
Clair Engle Lake	Trinity River	2,448	1960
Lewiston Lake	Trihity River	15	1963
Whiskeytown Lake	Clear Creek	241	1963
Spring Creek Debris	Spring Creek	6	1963
Keswick	Sacramento River	24	1948
Red Bluff Diversion	Sacramento River	4	1966
Black Butte	Stony Creek	160	1963
Jenkinson Lake	Cosumnes River	41	1955
Folsom Lake	American River	1,010	1955
Lake Natoma (Nimbus)	American River	9	1955
Contra Loma	unnamed stream	2	1963
San Luis*	offstream	2,039	1967
O'Neill*	offstream	28	1966
Los Banos*	Los Banos Creek	17	1966
Little Panoche*	Little Panoche Creek	7	1966
Millerton Lake	San Joaquin River	520	1944
Auburn	American River	2,326	under construction
New Melones	Stanislaus River	2,400	under construction

Source: Department of Water Resources Bulletin No. 160-74

\*Joint use facilities with State Water Project.

fall. In addition, the Bureau of Reclamation also is planning other water storage and conveyance facilities to serve farms and communities in the Central Valley. Under construction are Auburn Dam (construction has been suspended by the President of the United States pending a report on seismic safety due this summer) and the Auburn-Folsom South Unit in the eastern Sacramento and San Joaquin counties and the Tehama-Colusa Canal in the western Sacramento Valley. New Melones Dam on the Stanislaus River is under construction by the U. S. Army Corps of Engineers and will be operated by the Bureau of Reclamation as part of the Central Valley Project. The San Felipe Unit is an authorized unit of the Central Valley Project to serve areas in the central coastal area from San Luis Reservoir.

#### State Water Project

The State Water Project has facilities which extend from Plumas County in the north to Riverside County in the south. When in full operation, shortly after the year 2000, it will deliver 4,230,000 acre-feet of water annually to service areas in Northern, Central, and Southern California. The 444-mile long California Aqueduct is the principal water transportation facility of the overall project which now includes 20 dams and reservoirs, five power plants, and 17 pumping plants as well as an additional 100 miles of branch aqueducts.

The main storage facility is Lake Oroville in Butte County four miles northeast of Oroville. The inflow of water into Lake Oroville is partially regulated by three small completed reservoirs in Plumas County (Frenchman Lake, Antelope Lake, and Davis Lake). Two more reservoirs are planned for construction above Lake Oroville in the Upper Feather River area at a later date. A listing of the major storage facilities is shown in Table III-4.

Water is released from Lake Oroville to an underground hydroelectric power plant. A short distance downstream, a series of smaller dams and reservoirs store water for the pump-storage operation and regulate the release into the Feather River. Water released from the Oroville complex flows down the Feather River into the Sacramento River and then into the network channels of the Sacramento-San Joaquin Delta.

## Sacramento-San Joaquin Delta

TABLE III-4

## STATE WATER PROJECT MAJOR STORAGE FACILITIES

Storage Reservoir	Stream	Capacity (1,000 acre-feet)	First Year of Operation
Frenchman Lake	Feather River	55	1968
Antelope Lake	Feather River	23	1968
Davis Lake	Feather River	84	1968
Abbey Bridge	Feather River	45	(1984)
Dixie Refuge	Feather River	16	(1984)
Lake Oroville	Feather River	3,538	1968
Thermalito Diversion	Feather River	13	1968
Thermalito Forebay	Feather River	12	1968
Thermalito Afterbay	Feather River	57	1968
Clifton Court Forebay	Old River	29	1968
San Luis*	offstream	2,039	1967
O'Neill*	offstream	28	1966
Los Banos*	Los Banos Creek	17	1966
Little Panoche*	Little Panoche Creek	7	1966

Source: Department of Water Resources Bulletin No. 132-74

\*Joint use facilities with Central Valley Project.

Near the northern edge of the Delta, the North Bay Aqueduct, which is scheduled for completion in 1980, will deliver water to Napa and Solano counties. Interim facilities in operation at present by the State serve some supplemental water to Napa County with water made available by the U. S. Bureau of Reclamation's Solano Project.

At the southern edge of the Delta, water is lifted 244 feet by the Delta Pumping Plant into the California Aqueduct. The South Bay Aqueduct branches off the California Aqueduct at this point and delivers water as far west as San Jose.

Water is conveyed by the California Aqueduct to the San Joaquin Valley and Southern California. Additional storage is provided by the Federal-State San Luis Reservoir west of Los Banos. As previously described for the Central Valley Project, water delivered by both the Federal Delta-Mendota Canal and the

California Aqueduct during winter and spring is held in San Luis Reservoir for delivery during the summer and fall. Water is lifted into San Luis Reservoir from the two canals through a pump-generator plant. As needed, water is released back through the same facilities, the pumps acting as turbines for power generation.

South of San Luis Reservoir, the California Aqueduct transports the water southward. The Dos Amigos Pumping Plant raises the water 125 feet, sufficient to provide gravity flow to Buena Vista. As water flows south in the San Joaquin Valley, three more pumping plants raise it an additional 968 feet to the A. D. Edmonston Pumping Plant at the northern base of the Tehachapi Mountains.

The A. D. Edmonston Pumping Plant lifts aqueduct water nearly 2,000 feet up the Tehachapi Mountains to an elevation of 3,165 feet above sea level. At that elevation, water crosses the mountains through a series of four tunnels connected by siphons, a total of about nine miles in length.

South of the Tehachapi Mountains, the Aqueduct divides. The West Branch, which carries the bulk of the water, passes through Pyramid Reservoir and terminates at Castaic Lake northwest of Los Angeles. The East Branch delivers water to contracting agencies in the Antelope Valley and in 1973 delivered the first water into Lake Perris in Riverside County which is the terminal reservoir of the aqueduct system.

#### City of Vallejo

The City of Vallejo exports water from the Delta for municipal and industrial use. The City diverts water from Cache Slough and transports it in a pipeline to its Fleming Hill water treatment plant. In addition to supplying its citizens, Vallejo sells raw water to the City of Fairfield and Travis Air Force Base and treated water to Mare Island Naval Shipyard.

#### Summary of Water Exports From the Delta

A summary of water exports from the Sacramento-San Joaquin Delta is presented in Table III-5 and shown graphically on Figure III-4. The record displayed on Figure III-4 has been extended with unpublished data from DWR and shows that water exports have continued to increase.

## Sacramento-San Joaquin Delta

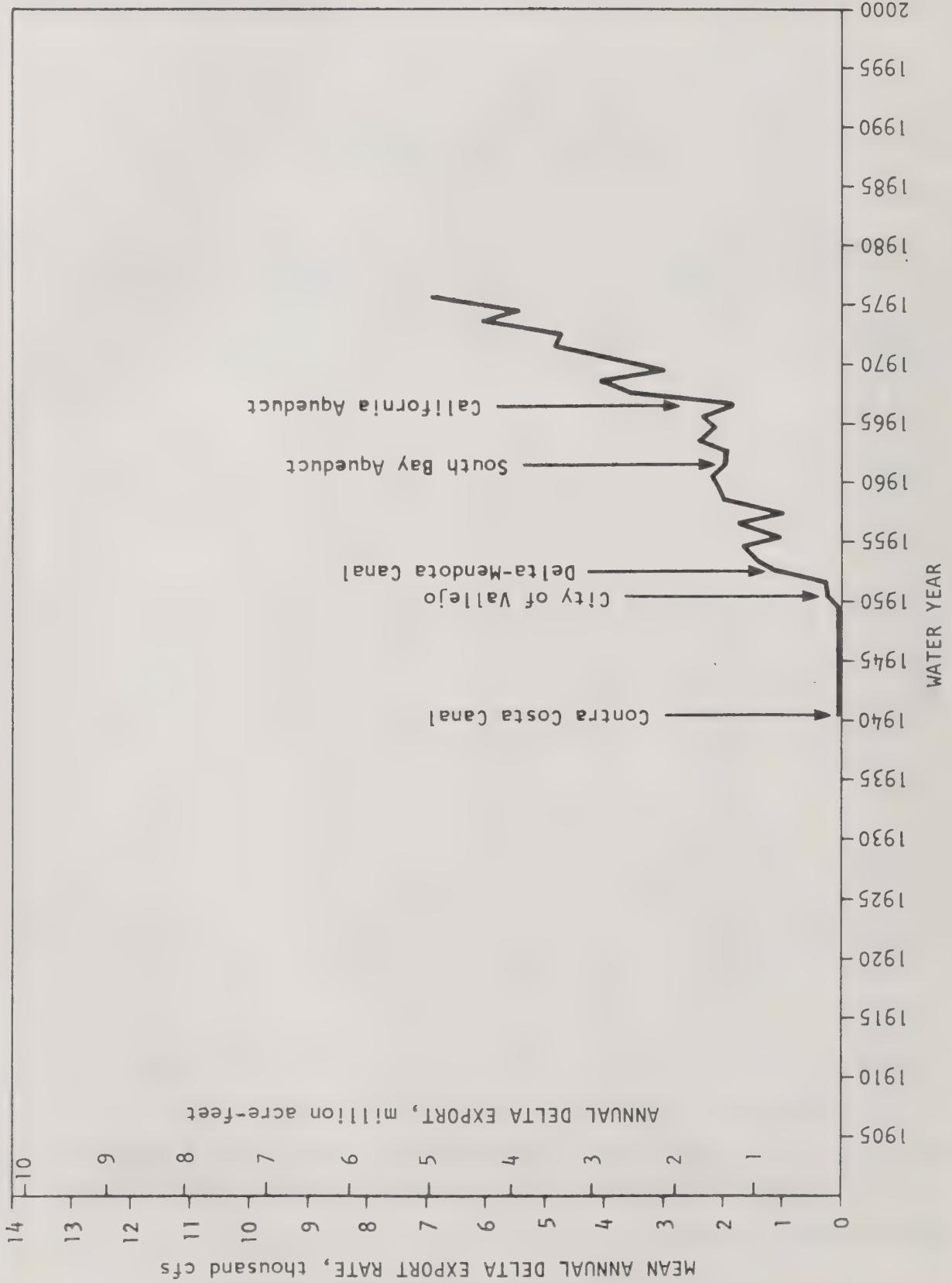
TABLE III-5

SUMMARY OF WATER EXPORTS  
SACRAMENTO-SAN JOAQUIN DELTA  
(1,000 acre-feet)

Water Year	Delta-Mendota Canal	Contra Costa Canal	California Aqueduct	City of Vallejo	Total
1940-41	-	5	-	-	5
1941-42	-	6	-	-	6
1942-43	-	8	-	-	8
1943-44	-	14	-	-	14
1944-45	-	14	-	-	14
1945-46	-	16	-	-	16
1946-47	-	23	-	-	23
1947-48	-	25	-	-	25
1948-49	-	34	-	-	34
1949-50	-	32	-	-	32
1950-51	164	30	-	-	194
1951-52	167	31	-	-	198
1952-53	784	34	-	6	824
1953-54	1,004	42	-	8	1,054
1954-55	1,131	48	-	12	1,191
1955-56	726	44	-	11	781
1956-57	1,181	54	-	9	1,244
1957-58	663	48	-	11	722
1958-59	1,341	69	-	11	1,421
1959-60	1,389	76	-	15	1,480
1960-61	1,488	78	-	14	1,580
1961-62	1,357*	72	-	14	1,443
1962-63	1,343*	63	-	13	1,419
1963-64	1,647*	82	-	11	1,740
1964-65	1,472*	72	-	15	1,559
1965-66	1,599*	84	-	14	1,697
1966-67					1,340
1967-68					2,579
1968-69					2,964
1969-70					2,179
1970-71					2,888

Source: California Department of Water Resources Memorandum, Estimates of Delta Water Supply and Disposal, December 16, 1971 and March 21, 1977

\*Includes water purchased for the South Bay Aqueduct.



TOTAL ANNUAL HISTORIC DELTA EXPORT

JBGA/DLF/RTC 9/77

FIGURE 111-4

## INTERNAL WATER USE

Internal water use results from consumptive use within the Delta. For purposes of this study, consumptive use is defined as the summation of Delta uplands net use and Delta lowlands channel depletion minus Delta uplands runoff and Delta lowlands total precipitation. An estimated summary of historical internal water use is presented in Table III-6 and shown graphically on Figure III-5. The 50-year mean net internal water use is 945,000 acre-feet per year.

## HISTORICAL NET DELTA OUTFLOW

In the past, many attempts have been made to actually measure the Delta outflow, i.e., the net flow past Chipp's Island. Due to the complex hydrodynamics in the area and the extensive tidal flows, however, these attempts have been futile. Because of this the California Department of Water Resources and the U. S. Bureau of Reclamation have developed a method to estimate the net Delta outflow. Basically, the method of estimating the net flow sums all inflows to the Delta and subtracts from that sum the internal uses and the exports.

In 1971, the Department's Division of Resources Development published a memorandum report entitled "Estimates of Delta Water Supply and Disposal." The purpose of that report was to set forth in a single reference pertinent information on Delta inflow, internal use, export, and outflow for differing past and projected future levels of development. The data presented in that report were selected from available studies and information, using those judged most nearly representative of the water planning outlook described by Bulletin No. 160-70, "Water for California, the California Water Plan, Outlook in 1970."

As to adequacy of the data presented, the Department stated:

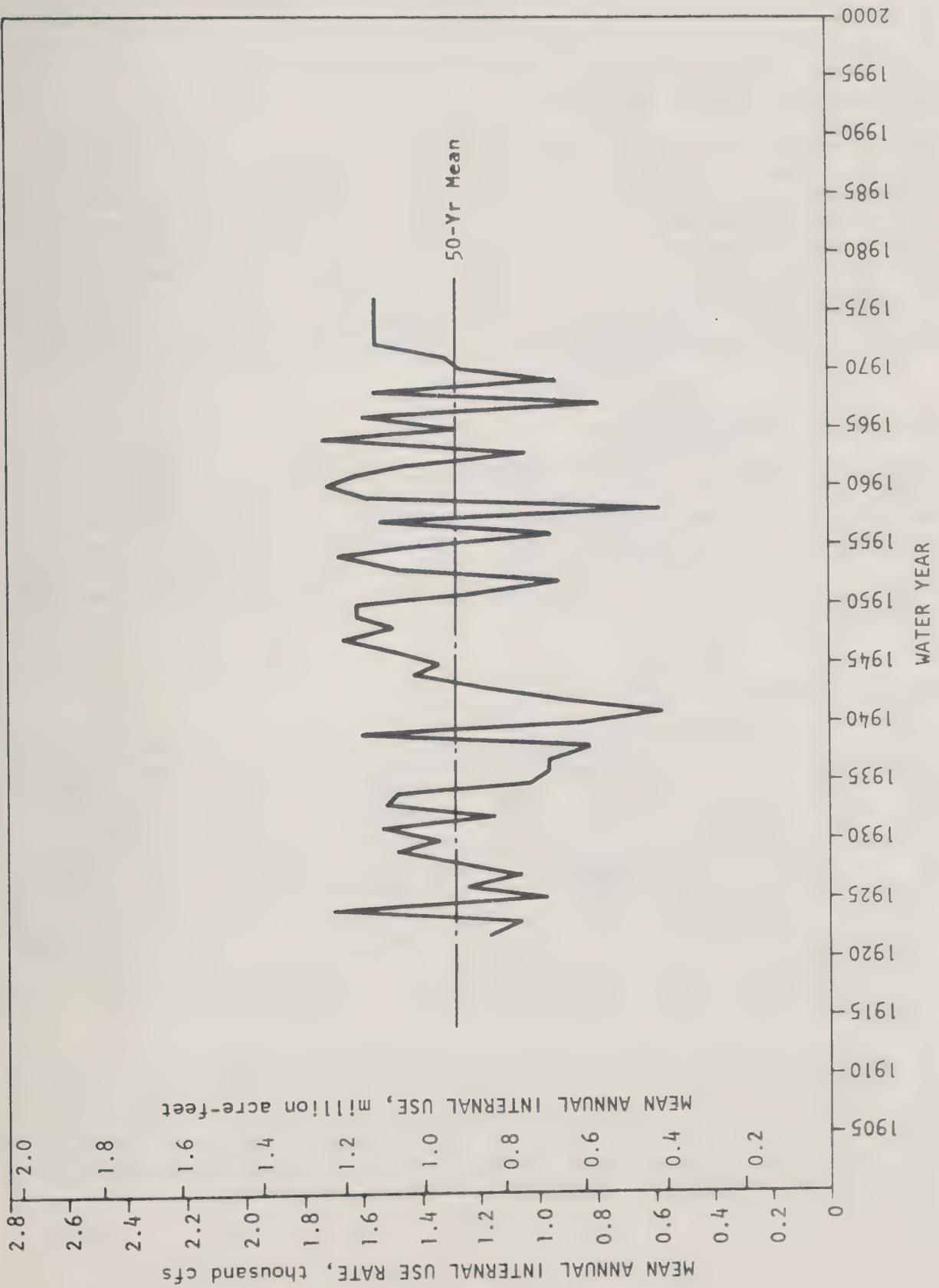
"We believe the monthly figures presented herein are adequate for most Delta study purposes at this time. However, the users should be aware that the forecasts of probable future conditions frequently change because of newer data, revised development projections and new policies or regulations. These changes can render current estimates obsolete, often within a span of only several years."

TABLE III-6

ESTIMATED HISTORIC DELTA INTERNAL NET USE  
(1,000 acre-feet)

Water Year	Use	Water Year	Use
1921-22	853	1947-48	1,103
1922-23	782	1948-49	1,188
1923-24	1,249	1949-50	1,187
1924-25	714	1950-51	899
1925-26	915	1951-52	690
1926-27	773	1952-53	1,081
1927-28	923	1953-54	1,233
1928-29	1,090	1954-55	1,082
1929-30	984	1955-56	706
1930-31	1,120	1956-57	1,127
1931-32	848	1957-58	443
1932-33	1,113	1958-59	1,159
1933-34	1,090	1959-60	1,259
1934-35	751	1960-61	1,196
1935-36	709	1961-62	1,064
1936-37	712	1962-63	771
1937-38	546	1963-64	1,271
1938-39	1,176	1964-65	943
1939-40	638	1965-66	1,170
1940-41	434	1966-67	594
1941-42	672	1967-68	1,145
1942-43	871	1968-69	693
1943-44	1,050	1969-70	931
1944-45	983	1970-71	968
1945-46	1,095		
1946-47	1,226	50-yr Mean	945

Source: California Department of Water Resources Memorandum,  
Estimates of Delta Water Supply and Disposal, December 16,  
1971 and March 21, 1977



ESTIMATED ANNUAL  
HISTORIC DELTA NET INTERNAL USE  
JBGA/DLF/RTC 9/77

FIGURE III-5

Computed Net Delta Outflow

The computed historical net Delta outflow (i.e., inflow minus internal use and export) for the 50-year period (1921-22 through 1970-71 water years) is available in the Department's December 16, 1971, memorandum and the March 21, 1977, update. A chronology of that data is presented on Figure III-6. As shown on Figure III-6, the average annual net Delta outflow varied from a low of 6,530 cfs in the 1923-24 water year to a high of 73,200 cfs in the 1937-38 water year. During the 50-year period (1921-22 through 1970-71 water years) the average annual net Delta outflow was 29,500 cfs.

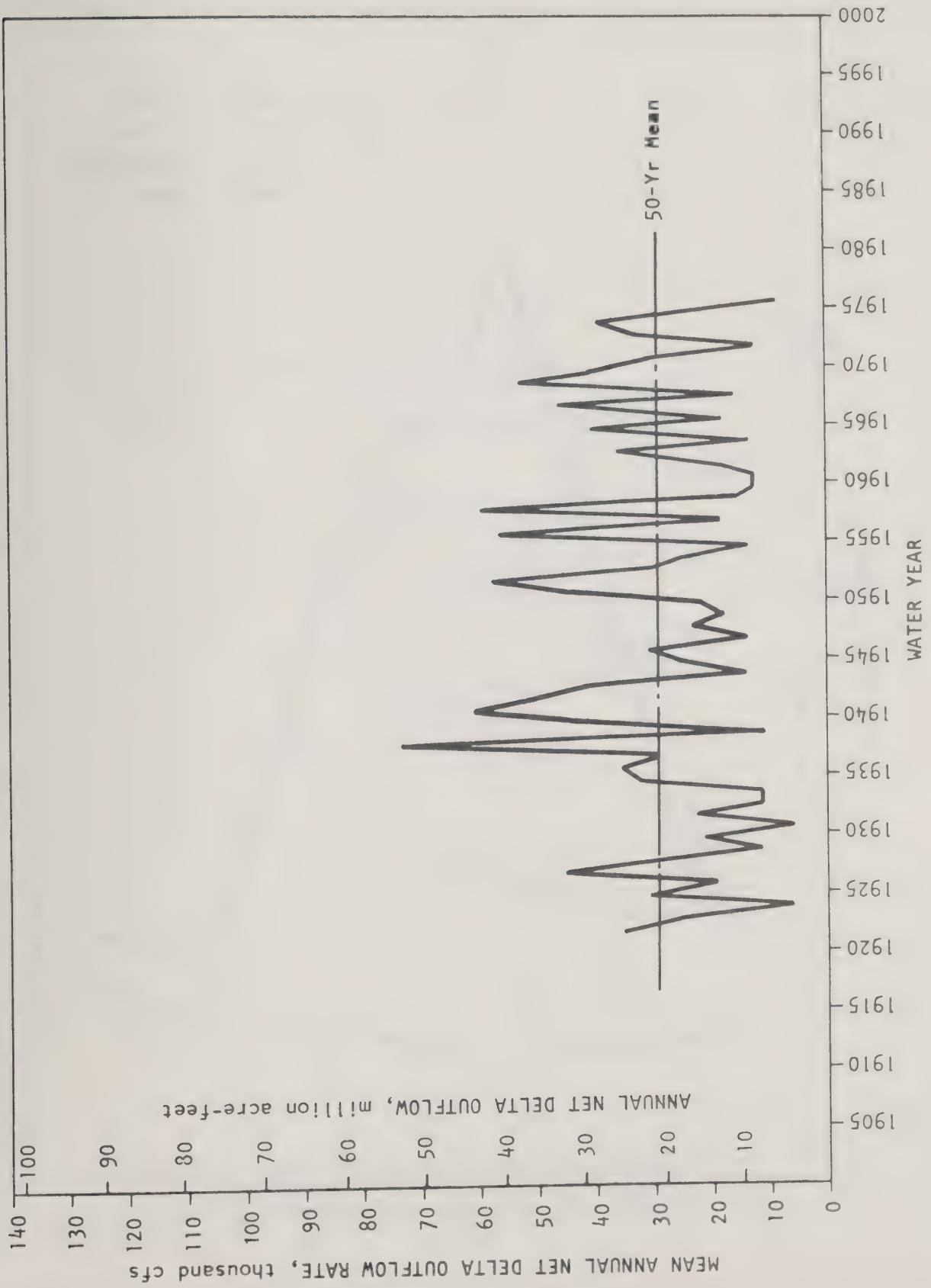
Monthly Variation

Although the previous four figures presented only average annual data, the Department's documents contained monthly values for the entire 50-year period for all components. As one would expect, all components vary considerably from month to month. Figure III-7 is presented to illustrate this variation for Delta inflow, outflow, internal use, and export. The values shown are monthly 50-year mean values.

Maximum Month Outflow

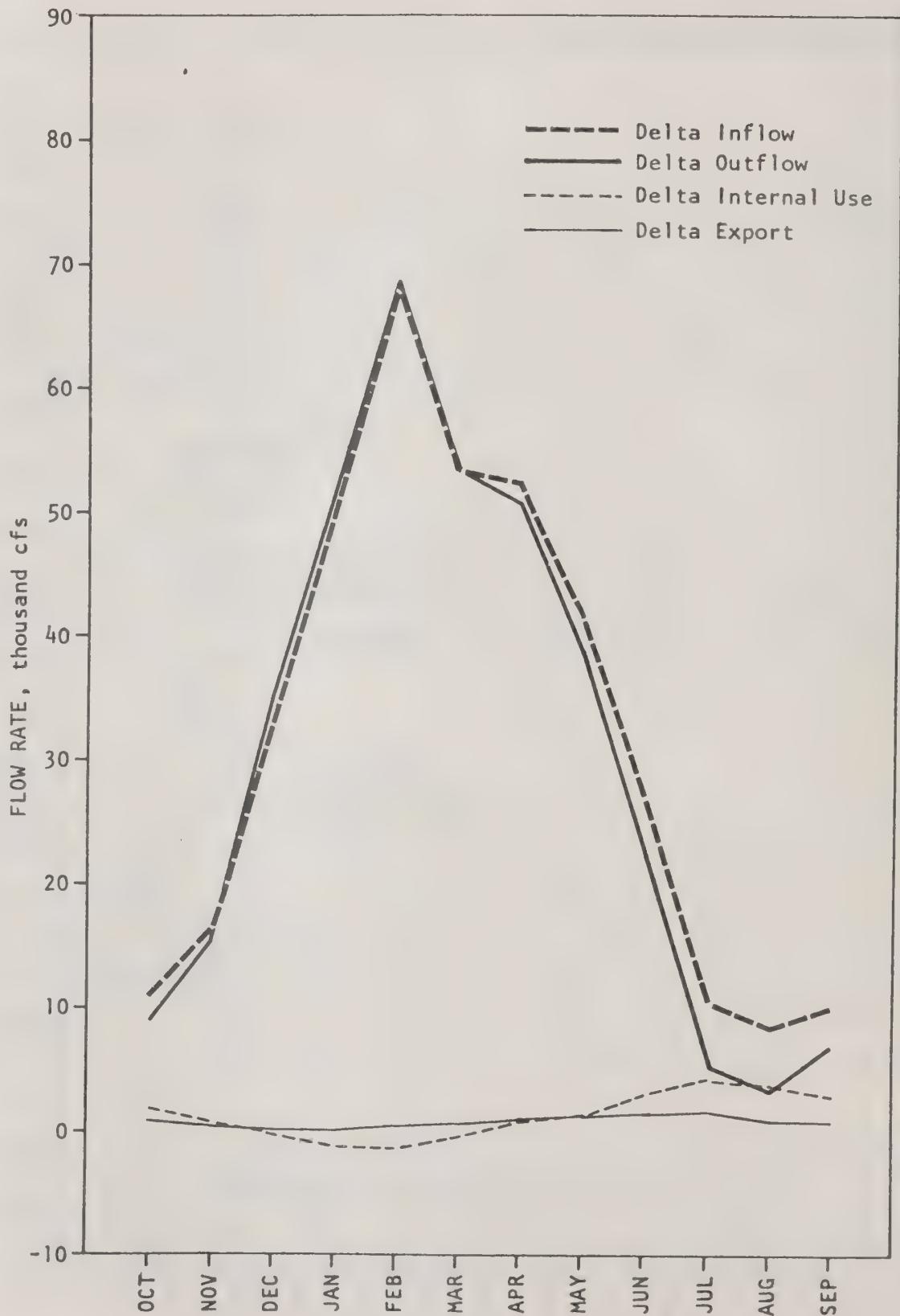
It has been postulated (Kelley, 1977) that winter flood flows are necessary to preserve salinity stratification in San Francisco Bay. Such stratification causes a rapid upstream bottom flow that resuspends sediments, absorbs pollutants, and prevents undesirable algal blooms. Such currents may also be necessary for the upstream migration of young shrimps and crabs to brackish water nursery areas. Based on the limited data available, Kelley believes that salinity stratification occurs down to near the middle of Central San Francisco Bay whenever the Delta outflows exceed about one million acre-feet in a month (16,800 cfs). Generally, these high flows occur for a seven-month period during the year (see Figure III-7).

The maximum month net Delta outflows for the 50-year base period are presented on Figure III-8. As shown, the maximum month flows have varied from a low of 17,200 cfs in 1930-31 to a high of 194,000 cfs in 1937-38, 1955-56, and 1969-70. This would indicate that historically there has always been at least one month each year when the proposed necessary flood flows have occurred.



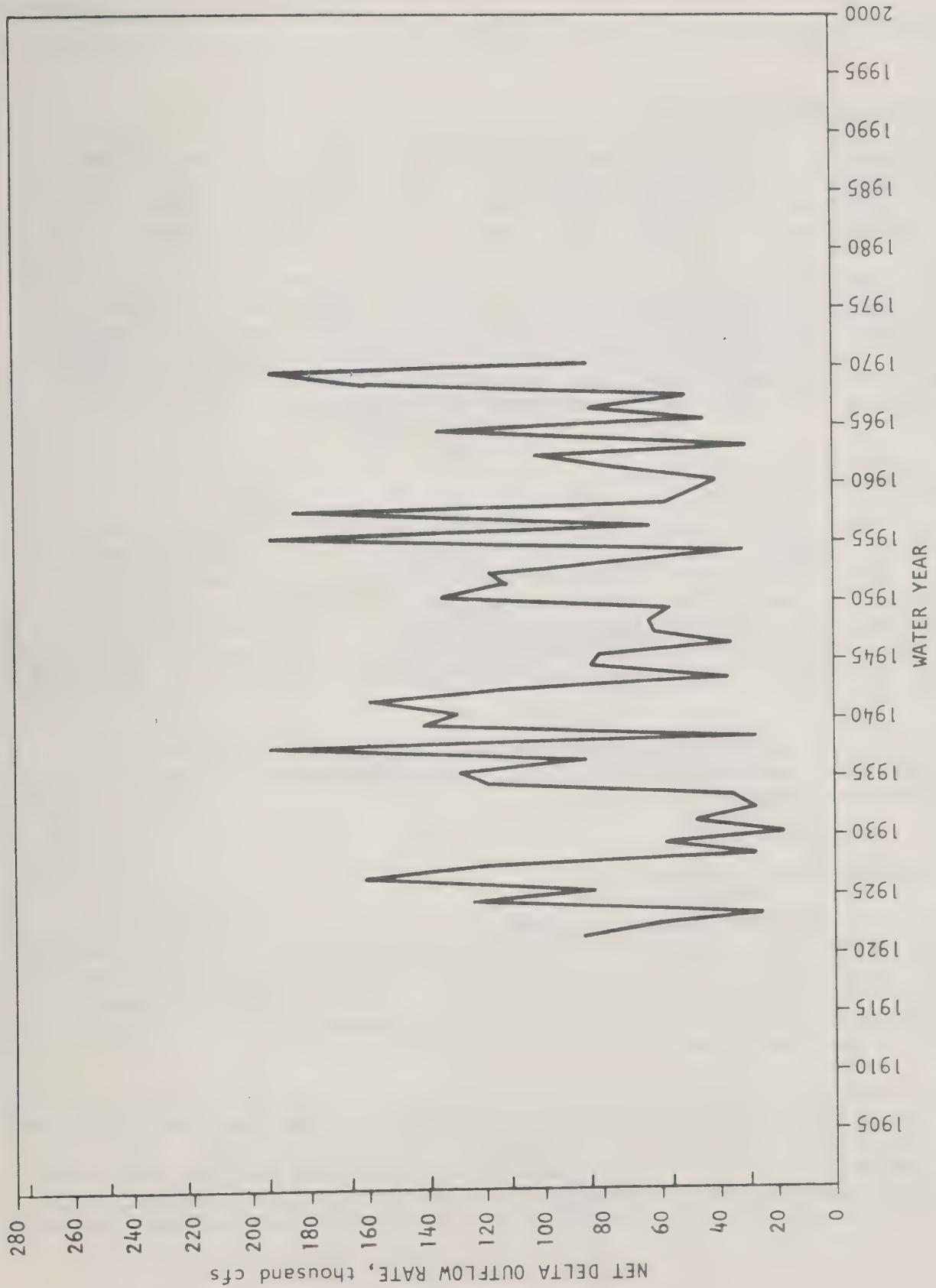
ESTIMATED HISTORIC AVERAGE ANNUAL NET  
DELTA OUTFLOW AT CHIPPS ISLAND  
JBGA/DLF/RTC 9/77

FIGURE IIII-6



ESTIMATED HISTORIC MONTHLY DELTA WATER SUPPLY  
AND DISPOSAL  
50-YEAR MEAN (1921-22 through 1970-71)  
JBGA/DLF/RTC 9/77

FIGURE III-7



HISTORIC MAXIMUM MONTH NET DELTA OUTFLOW  
AT CHIPPS ISLAND  
JBGA/DLF/RTC 9/77

FIGURE III-8

### Minimum Month Outflow

Minimum net Delta outflows are important when considering salinity objectives for the Bay and Delta. For instance, in order to meet the 4,000 mg/l chloride objective at Chipps Island (Decision 1379) it is necessary to maintain a net Delta outflow of about 4,500 cfs.

The historical minimum month net Delta outflows are presented on Figure III-9. As shown on Figure III-9, the general trend in historical minimum monthly net Delta outflows has been upward. Prior to the construction of Shasta Dam and Reservoir, in 1940, negative net Delta outflows were common. Since then, however, negative net Delta outflows have not occurred.

### Critical Period

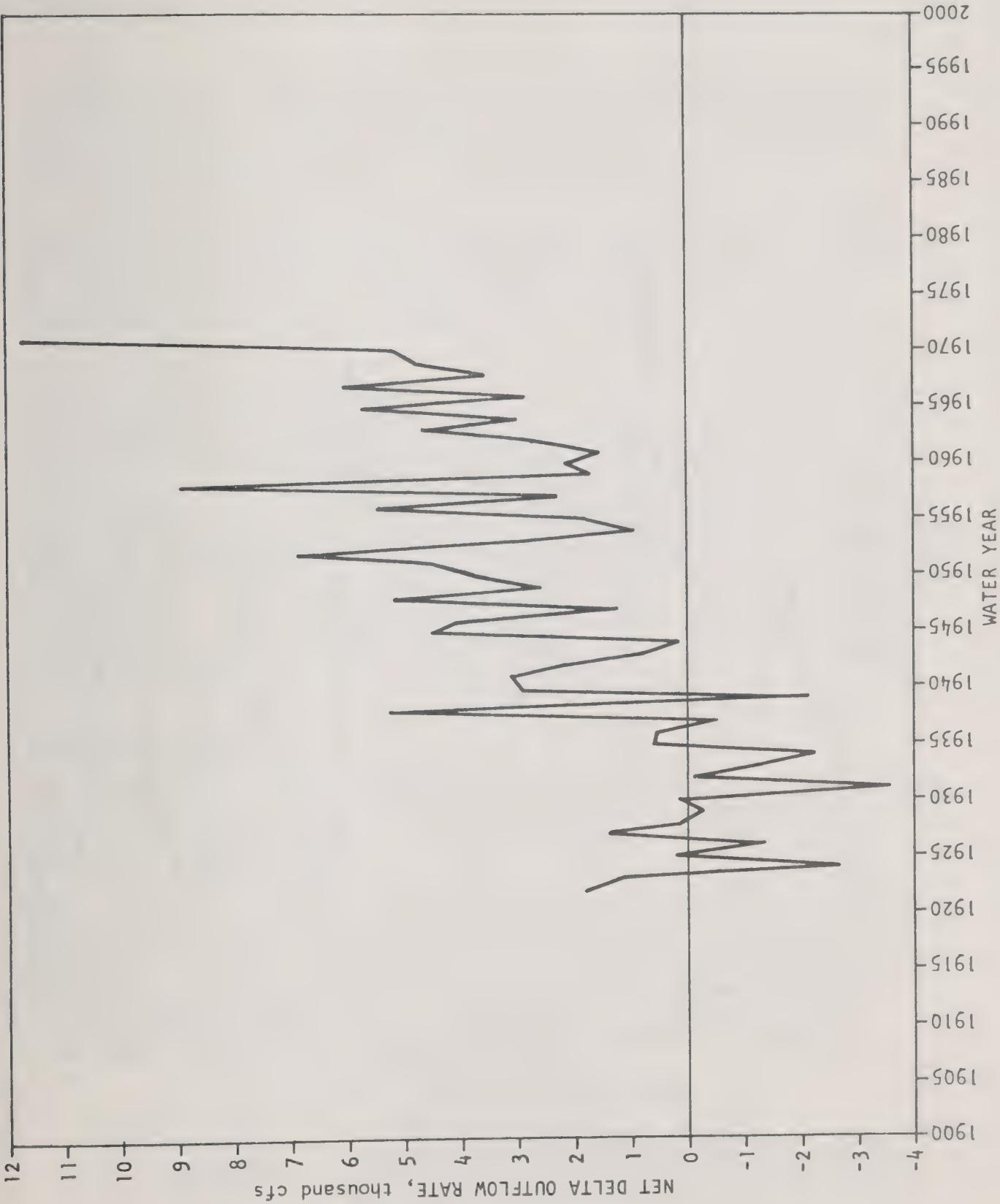
The Department of Water Resources has defined the "critical period" as water years 1928-29 through 1933-34. During this six-year period the annual average net Delta outflow was only 48 percent of the annual average net Delta outflow of the 50-year base period. The average monthly flows for the six-year critical period are shown on Figure III-10. During that period the 50-year mean net Delta outflow was exceeded only 13 months, or 15 percent of the time.

During that same period negative net Delta outflows occurred during nine months and in 1931 they persisted for three consecutive months.

### Delta Outflow Index

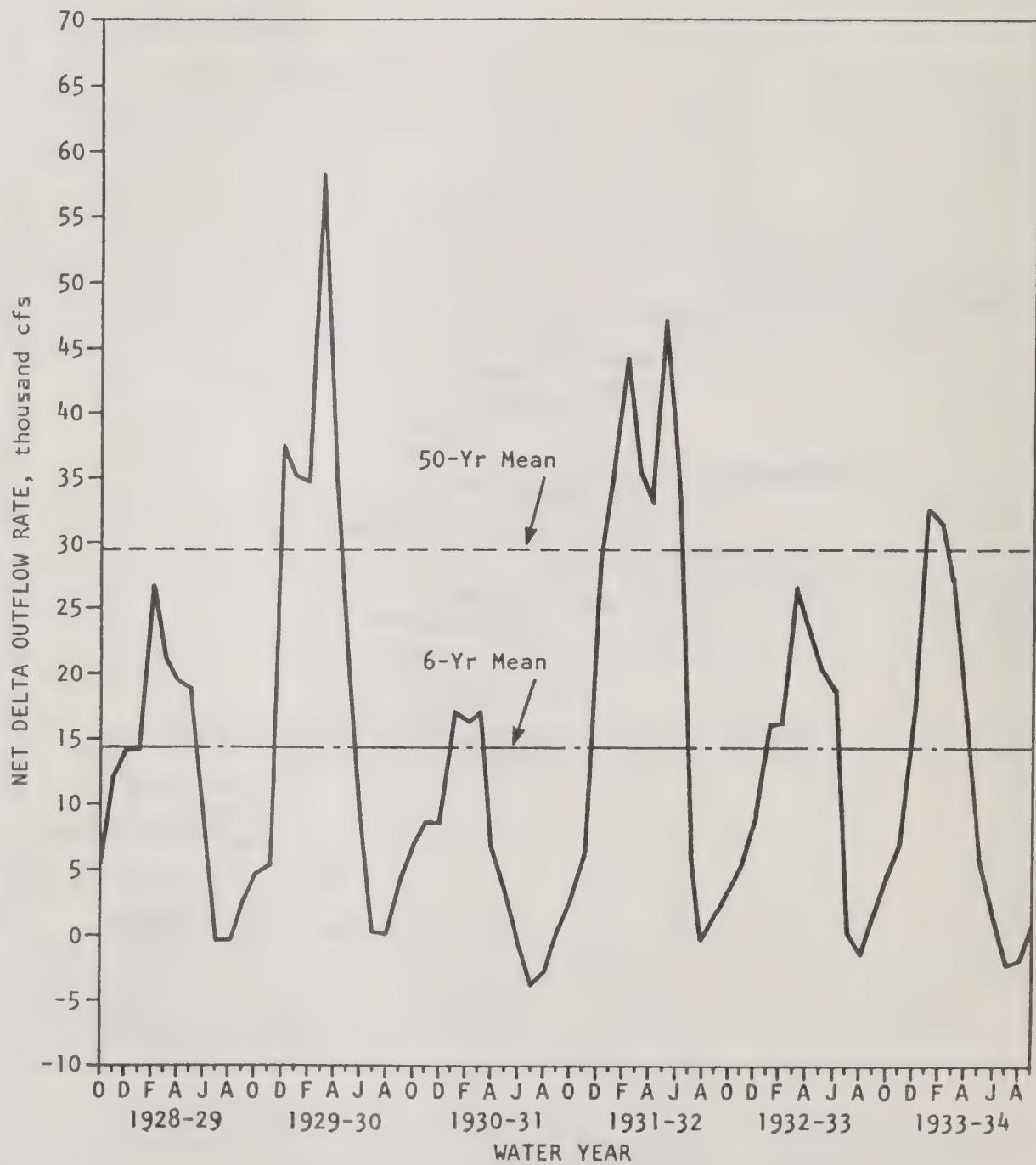
The U. S. Bureau of Reclamation, in cooperation with the California Department of Water Resources, has developed a method to estimate the net Delta outflow on a daily basis. The result is called the "Delta Outflow Index." It is termed an index because it does not include all the components that contribute to the net Delta outflow.

The index is computed as follows. The flow of the Sacramento River at Sacramento is added to the flow of the San Joaquin River at Vernalis. This total is called Delta inflow. Next the flows at the Bureau's Tracy and Contra Costa pumping plants are added to the Clifton Court Forebay (California Aqueduct) inflow. This total is called total export. The estimated net consumptive use



HISTORIC MINIMUM MONTH NET DELTA OUTFLOW  
AT CHIPPS ISLAND  
JBGA/DLF/RTC 9/77

FIGURE III-11-4



ESTIMATED HISTORIC NET DELTA OUTFLOW  
CRITICAL PERIOD (1928-29 through 1933-34)  
JBGA/DLF/RTC 9/77

FIGURE III-10

is then added to the total export to determine the total demand. The total demand is then subtracted from the total inflow to determine the Delta Outflow Index. These computations are made and recorded on a daily basis by the Bureau.

Thus, the Delta Outflow Index does not include the effects of inflow from the East Side Streams, other minor streams, the City of Vallejo's export, or the contribution to outflow from the Yolo Bypass. However, it is an indication of the daily outflow, especially during the low-flow, summer months.

#### **DELTA INFLOW WATER QUALITY**

The California Department of Water Resources routinely monitors the quality of the waters flowing into the Sacramento-San Joaquin Delta, as part of its Surface Water Monitoring Program. Water quality data are available for the following streams: Sacramento River at Freeport, San Joaquin River at Mossdale Bridge, Mokelumne River at Woodbridge, Calaveras River near Jenny Lind, and Cosumnes River at McConnell. Historical data are available for the following parameters: dissolved oxygen, temperature, pH, electrical conductivity, calcium, magnesium, sodium, potassium, carbonate, bicarbonate, sulfate, chloride, nitrate, boron, silica, total dissolved solids, hardness, and turbidity.

#### Sacramento River

The Department of Water Resources has been monitoring the quality of the Sacramento River at Freeport on a monthly basis since June 1960. A summary of the abstracted data for this station is presented in Table III-7.

The quality of the Sacramento River at Freeport, on the basis of the reported parameters, is very good. During the 11-year period analyzed, the annual (water year) means of the various parameters varied as follows:

Temperature	13 to 16°C
Turbidity	10 to 37 tu
pH	7.3 to 7.5 units
Electrical conductivity	128 to 175 micromhos
Chloride	4.6 to 8.8 mg/l
Total nitrogen	0.48 to 0.70 mg/l (four years data)
Total phosphorus	0.12 to 0.18 mg/l (five years data)
Silica	15.9 to 21.0 mg/l (eight years data)

TABLE III-7  
SUMMARY OF HISTORICAL ANNUAL WATER QUALITY OF  
SACRAMENTO RIVER AT FREEPORT

Water Year	Water Quality Parameter										
	Temperature °C	Turbidity	pH	EC	Chloride mg/l	Org N mg/l	NH <sub>3</sub> -N mg/l	NO <sub>3</sub> -N mg/l	P mg/l	Silica mg/l	Flow cfs*
1960-1961											
Range	7-23	7-150	7.1-7.5	123-259	3.8-15	-	-	-	-	19.0-23.0	7690-38700
Mean	15	31	7.3	175	8.8	-	-	-	-	21.0	15900
Std. Dev.	5	41	0.1	36	3.2	-	-	-	-	2.8	9050
1961-1962											
Range	8-21	4-150	7.1-7.8	106-222	4.0-12	-	-	-	-	-	7080-43000
Mean	15	29	7.4	171	8.4	-	-	-	-	-	18100
Std. Dev.	5	39	0.2	40	2.2	-	-	-	-	-	11900
1962-1963											
Range	6-22	4-100	7.1-7.5	59-212	2.5-12	-	-	-	-	-	11500-61600
Mean	15	26	7.3	148	7.1	-	-	-	-	-	28200
Std. Dev.	5	27	0.1	48	3.2	-	-	-	-	-	16900
1963-1964											
Range	8-23	3-25	7.3-7.8	137-203	4.0-10	-	-	-	-	19.0-20.0	11100-24700
Mean	14	10	7.5	166	7.2	-	-	-	-	19.5	16100
Std. Dev.	6	6	0.2	20	2.0	-	-	-	-	0.7	4900
1964-1965											
Range	8-22	1-180	7.2-7.7	87-197	2.2-8.3	-	-	-	-	18.0-19.0	9720-71800
Mean	16	34	7.4	142	5.0	-	-	-	-	18.5	27300
Std. Dev.	5	48	0.2	33	1.8	-	-	-	-	0.7	19000
1965-1966											
Range	7-22	2-90	7.3-7.7	103-267	2.0-15	-	-	-	-	15.0-18.0	9580-34500
Mean	16	17	7.5	162	6.4	-	-	-	0.20	16.2	18500
Std. Dev.	5	28	0.2	40	3.3	-	-	-	-	1.3	7680

TABLE III-7  
(Continued)

SUMMARY OF HISTORICAL ANNUAL WATER QUALITY OF  
SACRAMENTO RIVER AT FREEPORT

Water Year	Water Quality Parameter										
	Temperature °C	Turbidity tu	pH	EC	Chloride mg/l	Org N mg/l	NH <sub>3</sub> -N mg/l	NO <sub>3</sub> -N mg/l	P mg/l	Silica mg/l	Flow cfs*
1966-1967											
Range	7-23	5-80	7.1-7.9	90-205	3.1-13	0.2-0.4	0.0-0.14	0.1-0.2	0.05-0.22	-	9120-51900
Mean	14	23	7.4	141	6.2	0.3	0.04	0.14	0.12	18.0	33500
Std. Dev.	5	21	0.2	34	3.0	0.1	0.05	0.05	0.05	-	16100
1967-1968											
Range	8-24	4-100	7.3-8.0	105-300	3.2-11	0.3-0.5	0.09-0.24	0.1-0.2	0.14-0.22	16.0-20.0	11400-41200
Mean	16	29	7.5	164	6.3	0.4	0.17	0.13	0.18	17.5	18600
Std. Dev.	5	30	0.2	45	2.4	0.1	0.05	0.03	0.05	1.1	9710
1968-1969											
Range	8-23	10-140	7.3-8.5	109-230	2.3-7.0	0.1-0.4	0.0-0.23	0.08-0.60	0.07-0.18	15.0-18.0	11600-71800
Mean	15	37	7.5	151	4.6	0.3	0.09	0.20	0.13	15.9	32300
Std. Dev.	5	42	0.3	31	1.8	0.1	0.08	0.15	0.04	1.1	19600
1969-1970											
Range	8-26	5-110	7.2-7.7	71-197	1.9-10	0.2-0.4	0.02-0.30	0.04-0.47	0.06-0.26	14.0-20.0	11800-70300
Mean	16	35	7.4	138	5.2	0.2	0.12	0.16	0.15	16.9	28100
Std. Dev.	6	28	0.1	29	2.5	0.1	0.12	0.10	0.05	1.6	21100
1970-1971											
Range	7-20	6-55	7.2-7.5	105-150	2.9-4.5	-	-	0.05-0.35	0.08-0.29	12.0-28.0	15300-64000
Mean	13	26	7.3	128	3.6	-	-	0.19	0.14	18.0	31500
Std. Dev.	4	17	0.1	14	0.6	-	-	0.10	0.07	4.2	14000

\*Measured at Sacramento

As shown in Table III-7, the average annual flow in the Sacramento River at Sacramento varied from a low of 15,900 cfs to a high of 33,500 cfs during the 1960-61 to 1970-71 period. This small range in flows is the result of upstream regulation (e.g., Shasta, Oroville, and Folsom reservoirs). The flow in the Sacramento River has a definite effect on Delta outflow, both with respect to quality and quantity, because the Sacramento River accounts for approximately 85 percent of the net Delta inflow on an annual basis.

### San Joaquin River

The Department of Water Resources has monitored the quality of the San Joaquin River at the Mossdale Bridge on a monthly basis since September 1952. A summary of the abstracted data for this station is presented in Table III-8.

As shown in Table III-8, the quality of the San Joaquin River at the Mossdale Bridge varies considerably, depending on the flow. During the period October 1952 through September 1976, the annual (water year) means of the various parameters varied as follows:

Temperature	15 to 19°C
Turbidity	10 to 63 tu
pH	7.4 to 8.8 units
Electrical conductivity	447 to 1,035 micromhos
Chloride	70 to 196 mg/l
Total nitrogen	1.50 to 2.68 mg/l (1972-76 only)
Total phosphorus	0.17 to 0.26 mg/l (1972-76 only)

Generally, the better quality water is associated with higher flows. During the 24-year period summarized in Table III-8, the mean annual (water year) flow in the San Joaquin River at Vernalis varied from a low of 606 cfs to a high of 14,100 cfs.

The San Joaquin River also has a definite effect on the characteristic of the net Delta outflow as it accounts for about 15 percent of the total volume on an annual basis.

### Mokelumne River

The quality of the Mokelumne River at Woodbridge has been monitored on a bi-monthly basis by the Department since April 1951. A summary of the abstracted data for this station is presented

TABLE III-8

SUMMARY OF HISTORICAL ANNUAL WATER QUALITY OF  
SAN JOAQUIN RIVER AT MOSSDALE BRIDGE

Water Year	Water Quality Parameter										
	Temperature °C	Turbidity	pH	EC	Chloride mg/l	Org N mg/l	NH <sub>3</sub> mg/l	NO <sub>3</sub> mg/l	P mg/l	Silica mg/l	Flow cfs
1952-1953											
Range	10-26	19-70	7.3-8.5	217-931	26-172	-	-	-	-	19.0-28.0	748-5950
Mean	18	30	8.0	557	97	-	-	-	-	23.5	2620
Std. Dev.	5	22	0.3	255	47	-	-	-	-	6.4	1640
1953-1954											
Range	10-25	2-30	7.1-8.4	102-947	10-176	-	-	-	-	9.3-28.0	542-6710
Mean	17	13	7.8	632	108	-	-	-	-	18.6	2370
Std. Dev.	5	10	0.4	265	52	-	-	-	-	13.2	1970
1954-1955											
Range	8-26	5-70	7.1-8.4	377-1000	50-196	-	-	-	-	24.0-28.0	416-2960
Mean	17	19	7.7	731	128	-	-	-	-	26.0	1350
Std. Dev.	6	20	0.4	215	48	-	-	-	-	2.8	780
1955-1956											
Range	9-27	5-95	7.0-7.9	135-866	6.2-390	-	-	-	-	15.0-24.0	799-27000
Mean	16	32	7.4	451	97	-	-	-	-	19.5	8750
Std. Dev.	6	29	0.3	273	107	-	-	-	-	6.4	8060
1956-1957											
Range	9-25	5-30	7.2-8.5	304-880	46-165	-	-	-	-	-	753-3760
Mean	17	14	7.8	661	113	-	-	-	-	31.0	1990
Std. Dev.	6	9	0.5	188	41	-	-	-	-	-	900
1957-1958											
Range	11-26	3-50	7.1-8.4	143-833	16-154	-	-	-	-	16.0-19.0	1540-27900
Mean	18	21	7.5	447	70	-	-	-	-	17.5	8380
Std. Dev.	6	17	0.4	249	47	-	-	-	-	2.1	9070

TABLE III-8  
(Continued)

SUMMARY OF HISTORICAL ANNUAL WATER QUALITY OF  
SAN JOAQUIN RIVER AT MOSSDALE BRIDGE

Water Year	Water Quality Parameter										
	Temperature °C	Turbidity	pH	EC	Chloride mg/l	Org N mg/l	NH <sub>3</sub> mg/l	NO <sub>3</sub> mg/l	P mg/l	Silica mg/l	Flow cfs
1958-1959	Range	10-28	0-85	7.2-8.4	340-1160	51-235	-	-	-	15.0-27.0	312-3630
	Mean	19	25	7.8	837	153	-	-	-	22.2	1730
	Std. Dev.	6	22	0.4	305	68	-	-	-	5.9	1240
1959-1960	Range	8-26	15-125	7.3-9.1	526-1420	72-307	-	-	-	19.0-34.0	222-1780
	Mean	18	38	7.9	1011	196	-	-	-	25.3	774
	Std. Dev.	7	31	0.5	258	69	-	-	-	7.8	494
1960-1961	Range	11-27	3-45	7.3-8.4	580-1430	21-280	-	-	-	14.0-75.0	104-1340
	Mean	18	20	7.8	1035	174	-	-	-	37.3	606
	Std. Dev.	6	13	0.5	290	74	-	-	-	32.9	465
1961-1962	Range	7-25	6-75	7.3-8.1	230-1460	31-289	-	-	-	15.0-24.0	410-5930
	Mean	17	23	7.7	819	141	-	-	-	19.5	2080
	Std. Dev.	6	19	0.2	384	80	-	-	-	6.4	2000
1962-1963	Range	8-26	5-150	7.1-9.0	114-953	8.5-172	-	-	-	16.0-25.0	1100-9340
	Mean	16	35	7.6	551	88	-	-	-	20.5	3930
	Std. Dev.	5	43	0.6	313	57	-	-	-	6.4	3240
1963-1964	Range	9-25	4-20	7.3-8.5	348-1300	48-272	-	-	-	26.0-28.0	383-3530
	Mean	18	12	8.0	914	163	-	-	-	27.0	1550
	Std. Dev.	5	6	0.5	331	77	-	-	-	1.4	1160

TABLE III-8  
(Continued)

SUMMARY OF HISTORICAL ANNUAL WATER QUALITY OF  
SAN JOAQUIN RIVER AT MOSSDALE BRIDGE

Water Year	Water Quality Parameter										
	Temperature °C	Turbidity	pH	EC	Chloride mg/l	Org N mg/l	NH <sub>3</sub> mg/l	NO <sub>3</sub> mg/l	P mg/l	Silica mg/l	Flow cfs
1964-1965											
Range	9-25	9-40	7.1-8.3	153-880	20-162	-	-	-	-	17.0-25.0	1220-14400
Mean	15	22	7.5	486	76	-	-	-	-	21.0	5260
Std. Dev.	5	10	0.4	259	48	-	-	-	-	5.7	3990
1965-1966											
Range	-	-	8.7-8.8	178-1280	17-259	-	-	-	-	-	440-6230
Mean	-	-	8.8	767	135	-	-	-	-	17.0	2350
Std. Dev.	-	-	0.1	434	92	-	-	-	-	-	2040
1966-1967											
Range	8-28	-	7.1-8.4	125-950	12-167	-	-	-	-	-	1100-20400
Mean	17	-	7.5	554	82	-	-	-	-	-	7690
Std. Dev.	6	-	0.4	276	51	-	-	-	-	-	7060
1967-1968											
Range	-	-	-	-	-	-	-	-	-	-	503-3630
Mean	-	-	-	-	-	-	-	-	-	-	1980
Std. Dev.	-	-	-	-	-	-	-	-	-	-	1220
1968-1969											
Range	-	-	-	-	-	-	-	-	-	-	1380-32600
Mean	-	-	-	-	-	-	-	-	-	-	14100
Std. Dev.	-	-	-	-	-	-	-	-	-	-	12700
1969-1970											
Range	11-27	20-160	7.2-8.4	180-850	19-151	-	-	-	-	-	1040-11100
Mean	16	63	7.7	470	77	-	-	-	-	-	4250
Std. Dev.	8	50	0.5	213	45	-	-	-	-	-	3300

III-33

Sacramento-San Joaquin Delta

TABLE III-8  
(Continued)SUMMARY OF HISTORICAL ANNUAL WATER QUALITY OF  
SAN JOAQUIN RIVER AT MOSSDALE BRIDGE

Water Year	Water Quality Parameter										
	Temperature °C	Turbidity	pH	EC	Chloride mg/l	Org N mg/l	NH <sub>3</sub> mg/l	NO <sub>3</sub> mg/l	P mg/l	Silica mg/l	Flow cfs
1970-1971											
Range	7-26	6-57	7.3-8.3	320-825	44-146	-	-	-	-	-	894-5200
Mean	16	24	7.7	613	100	-	-	-	-	-	2460
Std. Dev.	5	18	0.4	191	39	-	-	-	-	-	1550
1971-1972											
Range	7-25	4-20	7.3-9.0	370-1050	55-230	-	-	-	-	-	488-3120
Mean	17	10	7.9	695	132	-	-	-	-	-	1550
Std. Dev.	7	5	0.7	225	62	-	-	-	-	-	915
1972-1973											
Range	6-24	3-55	7.2-8.8	280-825	31-158	0.99-1.16	0.14-0.21	1.40-1.44	0.25-0.27	-	1070-7940
Mean	16	19	7.8	588	102	1.08	0.18	1.42	0.26	-	3300
Std. Dev.	6	13	0.6	161	40	0.12	0.05	0.03	0.01	-	2310
1973-1974											
Range	9-26	6-33	7.2-8.7	260-840	34-145	0.43-2.07	0.00-0.42	0.19-1.30	0.10-0.28	16.6-17.8	1610-7780
Mean	17	18	7.6	552	84	0.85	0.10	0.77	0.19	17.4	3840
Std. Dev.	6	8	0.4	167	35	0.44	0.13	0.26	0.05	0.7	1840
1974-1975											
Range	10-25	11-38	7.2-8.5	153-843	16-126	0.38-1.45	0.00-0.16	0.25-1.10	0.11-0.29	7.6-20.0	1680-6220
Mean	16	22	7.6	492	68	0.72	0.04	0.74	0.17	14.4	3910
Std. Dev.	5	8	0.3	176	29	0.26	0.04	0.24	0.05	2.8	1460
1975-1976											
Range	10-25	7-48	7.2-9.0	211-1300	28-248	0.20-3.30	0.00-0.43	0.19-2.30	0.10-0.43	0.8-20.0	671-4540
Mean	17	21	8.0	867	138	1.11	0.10	1.08	0.23	11.6	2110
Std. Dev.	5	10	0.6	319	65	0.74	0.12	0.55	0.09	5.0	1400

in Table III-9, which shows that the quality of the Mokelumne River at Woodbridge is excellent with respect to those parameters analyzed.

During the 1976 water year, the quality of the Mokelumne River at Woodbridge deteriorated badly, probably as the result of salinity intrusion. This is shown in the following tabulation which presents the ranges of the annual means for the October 1951 to September 1975 period along with the mean for the 1976 water year.

<u>Parameter</u>	<u>1951-75 Mean Range</u>	<u>1976 Mean</u>
Temperature	13 to 18°C	22°C
Turbidity	1 to 31 tu	22 tu
pH	6.7 to 7.3 units	8.1 units
Electrical conductivity	41 to 65 micromhos	875 micromhos
Chloride	0.9 to 4.1 mg/l	158 mg/l
Silica	9.2 to 14 mg/l	19 mg/l

During the October 1951 to September 1976 period, the annual (water year) average flow of the Mokelumne River at Woodbridge varied from a low of 42 cfs to a high of 1,470 cfs. From the available data, it does not appear that the Mokelumne River flow has a significant effect on the net Delta inflow.

#### Calaveras River

The Department of Water Resources has been monitoring the water quality in the Calaveras River near Jenny Lind on a monthly basis since April 1951. A summary of the abstracted historical data is presented in Table III-10.

The quality of the Calaveras River is very good with respect to the parameters analyzed. During the 15-year period of record, the annual (water year) mean values of the various parameters ranged as follows:

Temperature	12 to 15°C
Turbidity	2 to 34 tu
pH	7.4 to 7.9 units
Electrical conductivity	183 to 305 micromhos
Chloride	3.8 to 12 mg/l
Silica	9.0 to 18 mg/l

TABLE III-9

SUMMARY OF HISTORICAL ANNUAL WATER QUALITY OF  
MOKELUMNE RIVER AT WOODBRIDGE

Water Year	Water Quality Parameter										
	Temperature °C	Turbidity	pH	EC	Chloride mg/l	Org N mg/l	NH <sub>3</sub> mg/l	NO <sub>3</sub> mg/l	P mg/l	Silica mg/l	Flow cfs
1951-1952											
Range	8-22	0-70	6.5-7.4	36-77	0.7-4.5	-	-	-	-	-	44.4-4400
Mean	14	20	7.0	61	1.7	-	-	-	-	12.0	1470
Std. Dev.	5	21	0.3	13	1.1	-	-	-	-	-	1320
1952-1953											
Range	9-22	0-9	6.8-7.2	41-82	1.0-3.5	-	-	-	-	8.9-12.0	34.4-1450
Mean	15	5	7.0	55	2.3	-	-	-	-	10.1	474
Std. Dev.	4	3	0.2	10	0.9	-	-	-	-	1.7	463
1953-1954											
Range	8-22	0.5-11	6.8-7.8	39-67	0-3.0	-	-	-	-	8.8-9.7	26.4-1280
Mean	15	6	7.1	49	1.7	-	-	-	-	9.2	409
Std. Dev.	5	4	0.3	8	1.0	-	-	-	-	0.6	342
1954-1955											
Range	7-21	1-40	6.8-7.3	36-85	1.0-4.2	-	-	-	-	13.0-15.0	11-1040
Mean	15	6	7.0	61	2.7	-	-	-	-	14.0	334
Std. Dev.	4	11	0.2	17	1.0	-	-	-	-	1.4	312
1955-1956											
Range	7-21	1-40	6.8-7.1	31-52	1.9-2.2	-	-	-	-	9.3-12.0	49-2580
Mean	13	15	6.9	43	2.0	-	-	-	-	10.6	968
Std. Dev.	6	13	0.1	8	0.2	-	-	-	-	1.9	860
1956-1957											
Range	7-22	1-9	6.9-7.3	34-57	0.5-2.2	-	-	-	-	-	86.4-1640
Mean	15	4	7.1	42	1.4	-	-	-	-	10.0	482
Std. Dev.	4	3	0.1	6	0.5	-	-	-	-	-	434

TABLE III-9  
(Continued)

SUMMARY OF HISTORICAL ANNUAL WATER QUALITY OF  
MOKELUMNE RIVER AT WOODBRIDGE

Water Year	Water Quality Parameter										
	Temperature °C	Turbidity	pH	EC	Chloride mg/l	Org N mg/l	NH <sub>3</sub> mg/l	NO <sub>3</sub> mg/l	P mg/l	Silica mg/l	Flow cfs
1957-1958											
Range	7-20	1-40	6.9-7.3	30-70	1.0-4.0	-	-	-	-	9.0-13.0	285-3300
Mean	13	10	7.0	45	2.5	-	-	-	-	11.0	1130
Std. Dev.	4	13	0.1	13	0.9	-	-	-	-	2.8	1050
1958-1959											
Range	11-23	1-20	6.4-7.3	36-87	1.4-4.0	-	-	-	-	12.0-14.0	26-692
Mean	18	6	7.0	54	2.4	-	-	-	-	12.7	177
Std. Dev.	5	5	0.3	14	0.8	-	-	-	-	1.2	214
1959-1960											
Range	7-23	1-35	6.8-7.1	50-67	2.5-4.2	-	-	-	-	13.0-14.0	18-184
Mean	16	8	7.0	58	3.4	-	-	-	-	13.5	56
Std. Dev.	5	9	0.1	6	0.7	-	-	-	-	0.7	54
1960-1961											
Range	8-23	2-10	6.9-7.3	41-66	1.8-7.0	-	-	-	-	10.0-12.0	12-177
Mean	16	4	7.0	54	3.7	-	-	-	-	11.0	49
Std. Dev.	5	3	0.1	8	1.5	-	-	-	-	1.4	59
1961-1962											
Range	6-22	1-50	5.9-7.1	33-122	2.0-6.2	-	-	-	-	11.0-12.0	24-706
Mean	14	16	6.7	65	4.1	-	-	-	-	11.5	252
Std. Dev.	6	16	0.4	26	1.3	-	-	-	-	0.7	239
1962-1963											
Range	9-22	3-160	6.7-7.1	32-79	1.1-3.8	-	-	-	-	-	41-4820
Mean	14	31	7.0	41	2.2	-	-	-	-	12.0	989
Std. Dev.	5	45	0.1	13	0.8	-	-	-	-	-	1440

TABLE III-9  
(Continued)

SUMMARY OF HISTORICAL ANNUAL WATER QUALITY OF  
MOKELUMNE RIVER AT WOODBRIDGE

Water Year	Water Quality Parameter										
	Temperature °C	Turbidity	pH	EC	Chloride mg/l	Org N mg/l	NH <sub>3</sub> mg/l	NO <sub>3</sub> mg/l	P mg/l	Silica mg/l	Flow cfs
1963-1964											
Range	7-23	2-4	7.0-7.6	42-55	1.0-4.5	-	-	-	-	8.9-10.0	11-92
Mean	15	3	7.2	50	2.8	-	-	-	-	9.4	42
Std. Dev.	6	1	0.2	5	1.2	-	-	-	-	0.8	33
1964-1965											
Range	9-21	1-60	6.9-7.3	43-61	1.0-2.1	-	-	-	-	11.0-12.0	72-1760
Mean	14	16	7.1	48	1.4	-	-	-	-	11.5	770
Std. Dev.	5	22	0.1	7	0.4	-	-	-	-	0.7	756
1965-1966											
Range	9-19	1-4	6.7-7.3	40-60	1.0-2.8	-	-	-	-	-	22-1750
Mean	15	3	7.0	52	1.7	-	-	-	-	9.3	524
Std. Dev.	4	1	0.2	7	0.6	-	-	-	-	-	692
1966-1967											
Range	7-18	1-10	7.1-8.1	41-71	1.5-2.8	-	-	-	-	-	35-2600
Mean	14	4	7.3	62	2.1	-	-	-	-	-	933
Std. Dev.	4	3	0.4	13	0.6	-	-	-	-	-	1450
1967-1968											
Range	14-22	2-20	7.0-7.3	42-60	1.0-2.2	-	-	-	-	-	34-108
Mean	18	7	7.2	48	1.8	-	-	-	-	-	44
Std. Dev.	3	7	0.1	6	0.4	-	-	-	-	-	33
1968-1969											
Range	9-21	15-45	6.9-7.3	37-48	1.1-2.0	-	-	-	-	-	38-2360
Mean	16	30	7.1	41	1.6	-	-	-	-	-	979
Std. Dev.	5	21	0.2	5	0.5	-	-	-	-	-	1220

III-38

TABLE III-9  
(Continued)

SUMMARY OF HISTORICAL ANNUAL WATER QUALITY OF  
MOKELUMNE RIVER AT WOODBRIDGE

Water Year	Water Quality Parameter										
	Temperature °C	Turbidity	pH	EC	Chloride mg/l	Org N mg/l	NH3 mg/l	NO3 mg/l	P mg/l	Silica mg/l	Flow cfs
1969-1970											
Range	10-22	20-25	6.8-7.2	36-50	0.8-1.0	-	-	-	-	-	168-3180
Mean	16	22	7.0	42	0.9	-	-	-	-	-	872
Std. Dev.	5	4	0.1	5	0.1	-	-	-	-	-	1290
1970-1971											
Range	6-23	1-5	6.9-7.4	41-58	0.8-2.2	-	-	-	-	-	35-1438
Mean	15	3	7.1	47	1.5	-	-	-	-	-	491
Std. Dev.	5	3	0.1	4	1.0	-	-	-	-	-	362
1971-1972											
Range	6-22	1-3	7.0-7.3	44-52	1.9-2.2	-	-	-	-	-	40-806
Mean	14	2	7.1	48	2.1	-	-	-	-	-	133
Std. Dev.	6	1	0.1	3	0.2	-	-	-	-	-	217
1972-1973											
Range	8-19	1-18	7.0-7.3	47-54	2.9-3.6	-	-	-	-	-	55-1030
Mean	13	10	7.2	50	3.2	-	-	-	-	-	357
Std. Dev.	6	12	0.1	2	0.5	-	-	-	-	-	332
1973-1974											
Range	8-20	1-6	7.0-7.2	44-54	0.7-1.4	-	-	-	-	-	305-2340
Mean	14	4	7.1	48	1.0	-	-	-	-	-	1020
Std. Dev.	4	4	0.1	3	0.5	-	-	-	-	-	789
1974-1975											
Range	9-19	0-1	7.0-7.3	41-47	-	-	-	-	-	-	40-1230
Mean	14	1	7.2	45	-	-	-	-	-	-	531
Std. Dev.	4	1	0.1	2	-	-	-	-	-	-	365

III-39

TABLE III-9  
(Continued)

SUMMARY OF HISTORICAL ANNUAL WATER QUALITY OF  
MOKELUMNE RIVER AT WOODBRIDGE

Water Year	Water Quality Parameter										
	Temperature °C	Turbidity	pH	EC	Chloride mg/l	Org N mg/l	NH <sub>3</sub> mg/l	NO <sub>3</sub> mg/l	P mg/l	Silica mg/l	Flow cfs
1975-1976											
Range	13-26	1-48	7.3-8.9	42-1190	136-185	-	-	-	-	12.0-25.2	10-799
Mean	22	22	8.1	875	158	-	-	-	-	19	174
Std. Dev.	6	15	0.5	380	20	-	-	-	-	-	-

TABLE III-10

SUMMARY OF HISTORICAL ANNUAL WATER QUALITY OF  
CALAVERAS RIVER NEAR JENNY LIND

Water Year	Water Quality Parameter										
	Temperature °C	Turbidity tu	pH	EC micromhos	Chloride mg/l	Org N mg/l	NH <sub>3</sub> mg/l	NO <sub>3</sub> mg/l	P mg/l	Silica mg/l	Flow cfs
1951-1952											
Range	7-24	1-160	7.0-8.3	101-309	0.0-8.0	-	-	-	-	-	13-3230
Mean	16	34	7.6	185	4.0	-	-	-	-	17.0	442
Std. Dev.	6	49	0.5	53	2.3	-	-	-	-	-	928
1952-1953											
Range	10-27	1-20	7.5-8.3	145-332	3.0-14	-	-	-	-	15.0-19.0	0.1-719
Mean	17	8	7.9	220	5.9	-	-	-	-	16.3	119
Std. Dev.	6	6	0.3	47	2.8	-	-	-	-	2.3	198
1953-1954											
Range	8-24	2-30	7.0-8.2	161-261	2.0-10	-	-	-	-	-	25-354
Mean	15	12	7.7	198	4.7	-	-	-	-	18.0	143
Std. Dev.	5	10	0.3	34	2.2	-	-	-	-	-	102
1954-1955											
Range	6-27	1-65	6.8-8.1	138-306	3.0-12	-	-	-	-	-	0.0-2770
Mean	15	16	7.4	220	6.0	-	-	-	-	17.0	364
Std. Dev.	6	25	0.4	57	2.8	-	-	-	-	-	847
1955-1956											
Range	8-23	1-80	7.0-7.9	-	0.5-9.3	-	-	-	-	17.0-18.0	7.0-4030
Mean	16	11	7.4	243	4.9	-	-	-	-	17.5	509
Std. Dev.	5	25	0.3	-	2.8	-	-	-	-	0.7	1240
1956-1957											
Range	8-24	1-8	7.3-8.1	170-254	2.5-10	-	-	-	-	16.0-23.0	0.0-207
Mean	16	4	7.7	206	5.5	-	-	-	-	19.5	72
Std. Dev.	6	3	0.3	27	2.6	-	-	-	-	4.9	75

TABLE III-10  
(Continued)

SUMMARY OF HISTORICAL ANNUAL WATER QUALITY OF  
CALAVERAS RIVER NEAR JENNY LIND

Water Year	Water Quality Parameter											Flow cfs
	Temperature °C	Turbidity tu	pH	EC micromhos	Chloride mg/l	Org N mg/l	NH <sub>3</sub> mg/l	NO <sub>3</sub> mg/l	P mg/l	Silica mg/l		
1957-1958												1.9-12100
Range	8-24	1-80	7.3-7.9	107-292	2.0-12	-	-	-	-	-	-	1164
Mean	15	12	7.6	198	5.8	-	-	-	-	-	-	3449
Std. Dev.	5	22	0.2	63	3.5	-	-	-	-	-	-	
1958-1959												0.1-2410
Range	7-28	1-50	7.3-7.9	156-300	3.5-10	-	-	-	-	-	15.0	400
Mean	17	10	7.4	232	7.9	-	-	-	-	-	-	776
Std. Dev.	7	16	0.2	49	2.8	-	-	-	-	-	-	
1959-1960												1.9-57
Range	4-27	1-30	7.3-7.9	225-332	7.2-15	-	-	-	-	-	-	15
Mean	17	8	7.6	262	10.3	-	-	-	-	-	-	20
Std. Dev.	8	12	0.2	41	3.3	-	-	-	-	-	-	
1960-1961												0.5-45
Range	5-23	1-20	7.3-7.9	281-340	9.0-17	-	-	-	-	-	13.0	12
Mean	15	9	7.5	305	12.0	-	-	-	-	-	-	16
Std. Dev.	7	9	0.3	21	2.6	-	-	-	-	-	-	
1961-1962												0.9-3710
Range	7-27	1-60	7.2-8.2	130-364	5.0-21	-	-	-	-	-	16.0	738
Mean	16	14	7.5	276	11.1	-	-	-	-	-	-	1410
Std. Dev.	7	19	0.3	100	6.5	-	-	-	-	-	-	
1962-1963												0.2-2260
Range	10-22	1-40	7.3-8.2	119-354	2.9-16	-	-	-	-	-	15.0-18.0	305
Mean	16	9	7.6	228	7.6	-	-	-	-	-	16.5	655
Std. Dev.	4	13	0.3	79	4.9	-	-	-	-	-	-	

III-42

TABLE III-10  
(Continued)

SUMMARY OF HISTORICAL ANNUAL WATER QUALITY OF  
CALAVERAS RIVER NEAR JENNY LIND

Water Year	Water Quality Parameter										
	Temperature °C	Turbidity tu	pH	EC micromhos	Chloride mg/l	Org N mg/l	NH <sub>3</sub> mg/l	NO <sub>3</sub> mg/l	P mg/l	Silica mg/l	Flow cfs
1963-1964											
Range	7-23	1-10	7.3-8.8	193-308	5.0-11	-	-	-	-	-	8.0-73
Mean	14	3	7.9	239	6.8	-	-	-	-	12.0	35
Std. Dev.	6	3	0.4	40	2.1	-	-	-	-	-	18
1964-1965											
Range	9-16	-	6.9-8.3	134-358	2.0-15	-	-	-	-	12.0-15.0	2.0-1520
Mean	13	-	7.7	183	5.5	-	-	-	-	13.5	262
Std. Dev.	2	-	0.5	79	4.5	-	-	-	-	2.1	447
1965-1977											
Range	9-16	1-5	7.3-8.3	154-226	2.2-6.5	-	-	-	-	-	15-1040
Mean	12	2	7.8	184	3.8	-	-	-	-	9.0	158
Std. Dev.	2	2	0.3	21	1.3	-	-	-	-	-	283

III-43

During the 15-year period of record (1951-1966) the mean annual (water year) flow varied from 12 cfs to 1,164 cfs. However, the extremes were 0.0 cfs and 12,100 cfs. Since the Corps of Engineers began operating New Hogan Reservoir in 1964, there has always been a flow in the Calaveras River near Jenny Lind.

From the data presented, it does not appear that the Calaveras River inflow has a significant effect on the Delta outflow quantity or quality, especially since New Hogan Dam and Reservoir now control the flow.

#### Cosumnes River

The water quality of the Cosumnes River at McConnell has been monitored on a bi-monthly basis by the Department of Water Resources since July 1958. A summary of the abstracted historical data is presented in Table III-11.

The quality in the Cosumnes River is excellent with respect to the parameters analyzed. During the 11-year period of record shown, the annual (water year) mean values for the various parameters ranged as follows:

Temperature	12 to 15°C
Turbidity	3 to 70 tu
pH	7.2 to 7.6 units
Electrical conductivity	79 to 111 micromhos
Chloride	2.1 to 3.0 mg/l
Silica	17.4 to 18.5 mg/l*

\*Two years of data only.

The Cosumnes River at McConnell dries up most years for a period of from three to four months. When flowing, however, the mean annual (water year) flow varies from 86 cfs to 913 cfs.

From the limited data available, it appears that the Cosumnes River inflow has had no significant effect on either the Delta outflow quantity or quality.

#### DELTA OUTFLOW WATER QUALITY

The majority of the water quality information on Delta outflow has been collected by the U. S. Bureau of Reclamation and the California Department of Water Resources. In 1968, the Bureau began monitoring the quality of the Delta outflow as part of its

TABLE III-11

SUMMARY OF HISTORICAL ANNUAL WATER QUALITY OF  
COSUMNES RIVER AT McCONNELL

Water Year	Water Quality Parameter										
	Temperature °C	Turbidity tu	pH	EC	Chloride mg/l	Org N mg/l	NH3 mg/l	NO3 mg/l	P mg/l	Silica mg/l	Flow cfs
1958-1959											
Range	8-21	-	7.2-8.0	57-121	1.0-5.6	-	-	-	-	16.0-19.0	4.7-432
Mean	14	0	7.6	94	3.0	-	-	-	-	17.4	171
Std. Dev.	5	-	0.3	24	1.6	-	-	-	-	1.2	166
1959-1960											
Range	6-21	8-70	7.1-7.3	50-108	0.5-4.5	-	-	-	-	18.0-19.0	56-395
Mean	14	32	7.2	79	2.8	-	-	-	-	18.5	260
Std. Dev.	6	25	0.1	22	1.6	-	-	-	-	0.7	229
1960-1961											
Range	3-20	2-20	7.2-7.4	67-124	1.5-3.5	-	-	-	-	-	10-242
Mean	13	7	7.3	90	2.6	-	-	-	-	-	86
Std. Dev.	6	6	0.1	21	0.6	-	-	-	-	-	81
1961-1962											
Range	7-24	2-45	7.0-7.4	42-116	1.5-4.5	-	-	-	-	-	3.0-694
Mean	13	16	7.2	81	2.9	-	-	-	-	15.0	297
Std. Dev.	6	16	0.1	30	1.2	-	-	-	-	-	296
1962-1963											
Range	4-27	3-40	7.1-7.5	59-134	1.0-4.6	-	-	-	-	-	16-3060
Mean	15	14	7.3	96	2.7	-	-	-	-	19.0	737
Std. Dev.	7	13	0.1	28	1.1	-	-	-	-	-	1018
1963-1964											
Range	7-16	1-6	7.3-7.5	59-113	1.5-4.8	-	-	-	-	-	18-418
Mean	12	3	7.4	92	3.0	-	-	-	-	16.0	171
Std. Dev.	4	2	0.1	23	1.4	-	-	-	-	-	176

TABLE III-11  
(Continued)

SUMMARY OF HISTORICAL ANNUAL WATER QUALITY OF  
COSUMNES RIVER AT McCONNELL

Water Year	Water Quality Parameter										
	Temperature °C	Turbidity tu	pH	EC	Chloride mg/l	Org N mg/l	NH3 mg/l	NO3 mg/l	P mg/l	Silica mg/l	Flow cfs
1964-1965											
Range	10-25	2-200	7.1-8.1	61-100	1.3-4.5	-	-	-	-	-	426-1180
Mean	15	70	7.4	81	2.1	-	-	-	-	17.0	788
Std. Dev.	6	87	0.4	17	1.3	-	-	-	-	-	378
1965-1966											
Range	8-22	1-5	7.3-7.5	102-129	0.7-4.1	-	-	-	-	-	423-1880
Mean	14	3	7.4	111	2.5	-	-	-	-	15.0	913
Std. Dev.	7	2	0.1	15	1.7	-	-	-	-	-	838
1966-1967											
Range	8-16	2-90	7.1-7.3	45-113	0.3-5.1	-	-	-	-	-	-
Mean	12	28	7.2	84	2.8	-	-	-	-	-	-
Std. Dev.	3	41	0.1	32	2.2	-	-	-	-	-	-
1967-1968											
Range	11-13	10-15	7.3-7.3	70-108	1.4-2.2	-	-	-	-	-	524-622
Mean	12	12	7.3	89	1.8	-	-	-	-	-	573
Std. Dev.	1	4	0.0	27	0.6	-	-	-	-	-	69
1968-1969											
Range	-	-	-	-	-	-	-	-	-	-	-
Mean	8	80	7.2	103	2.2	-	-	-	-	-	3210
Std. Dev.	-	-	-	-	-	-	-	-	-	-	-

Delta-Suisun Bay Ecological Studies Program. This program was supplemented in 1973 by the Department's Delta Water Quality Management Program which was required by the State Water Resources Control Board's Decision 1379.

As a part of these programs, samples are collected at least monthly and analyzed for the following parameters: pH, dissolved oxygen, temperature, electrical conductivity, carbonate, bicarbonate, chloride, nitrate, silica, turbidity, total dissolved solids, organic nitrogen, orthophosphate, and total phosphate. In addition, heavy metals and pesticides are analyzed three times per year (January, May, and September).

A summary of this data is presented in Table III-12. Relationships between daily water quality data and Delta outflow, using the daily Delta Outflow Index, were derived for this study. Results for individual water quality parameters are discussed in the following paragraphs.

#### Temperature

During the period 1968-69 through 1975-76, the temperature of the Delta outflow varied from a low of  $6^{\circ}\text{C}$ ( $43^{\circ}\text{F}$ ) to a high of  $25^{\circ}\text{C}$  ( $77^{\circ}\text{F}$ ). As expected, temperature varies seasonally with low values occurring during the winter months (December-February) and high values occurring during the late summer months (July-September). There do not appear to be any significant trends in the temperature data except that low values are associated with high flows and mean values are lower for water years with higher net Delta outflows.

#### Turbidity

Turbidity of the Delta outflow ranged from a low of 10 to a high of 160 turbidity units during the period from October 1968 to September 1976. The relationship between turbidity and the Delta Outflow Index at Chipps Island, as shown on Figure III-11, is statistically significant at the 95% level of confidence. Higher turbidity levels are associated with higher fresh water outflows, which usually carry higher silt loads.

TABLE III-12

SUMMARY OF HISTORICAL ANNUAL WATER QUALITY OF DELTA OUTFLOW  
SACRAMENTO RIVER AT CHIPPS ISLAND<sup>a</sup>  
Water Year

Parameter	1968-1969	1969-1970	1970-1971	1971-1972	1972-1973	1973-1974	1974-1975	1975-1976
Temperature, °C								
Range	8-23	11-22	10-23	6-22	7-25	9-23	8-22	9-23
Mean	15.5	17.1	17.7	15.6	16.2	15.9	15.1	15.9
Standard Dev.	5.1	3.6	3.5	5.5	5.9	4.9	4.9	4.8
Turbidity, tu								
Range	25-160	26-100	15-70	18-60	21-110	22-132	18-72	10-84
Mean	58	52	34	32	43	43	29	27
Standard Dev.	45	23	16	12	21	24	13	17
pH								
Range	7.1-8.5	7.2-8.0	6.8-8.0	7.5-8.3	7.0-8.0	6.9-8.1	7.6-8.2	7.5-8.2
Mean	7.6	7.6	7.6	7.9	7.8	7.8	7.9	7.9
Standard Dev.	0.4	0.3	0.3	0.3	0.3	0.3	0.2	0.2
EC, µmhos								
Range	130-9000	160-9600	140-2550	382-12700	175-8571	125-2850	171-3760	716-12300
Mean	2163	3578	704	5200	2949	832	893	7650
Standard Dev.	3021	3565	767	3985	2892	926	981	3721
Chloride, mg/l								
Range	5.0-3100	5.0-3060	-	79-3470	14-2710	7.5-920	9.2-1220	163-4670
Mean	642	1080	-	1462	920	224	232	2552
Standard Dev.	1002	1151	-	1186	937	303	315	1370
Organic-N, mg/l								
Range	-	-	0.18-0.71	0.21-1.10	0.40-0.60	0.16-0.59	-	-
Mean	-	-	0.36	0.49	0.46	0.32	-	-
Standard Dev.	-	-	0.20	0.27	0.09	0.14	-	-

TABLE III-12  
(Continued)

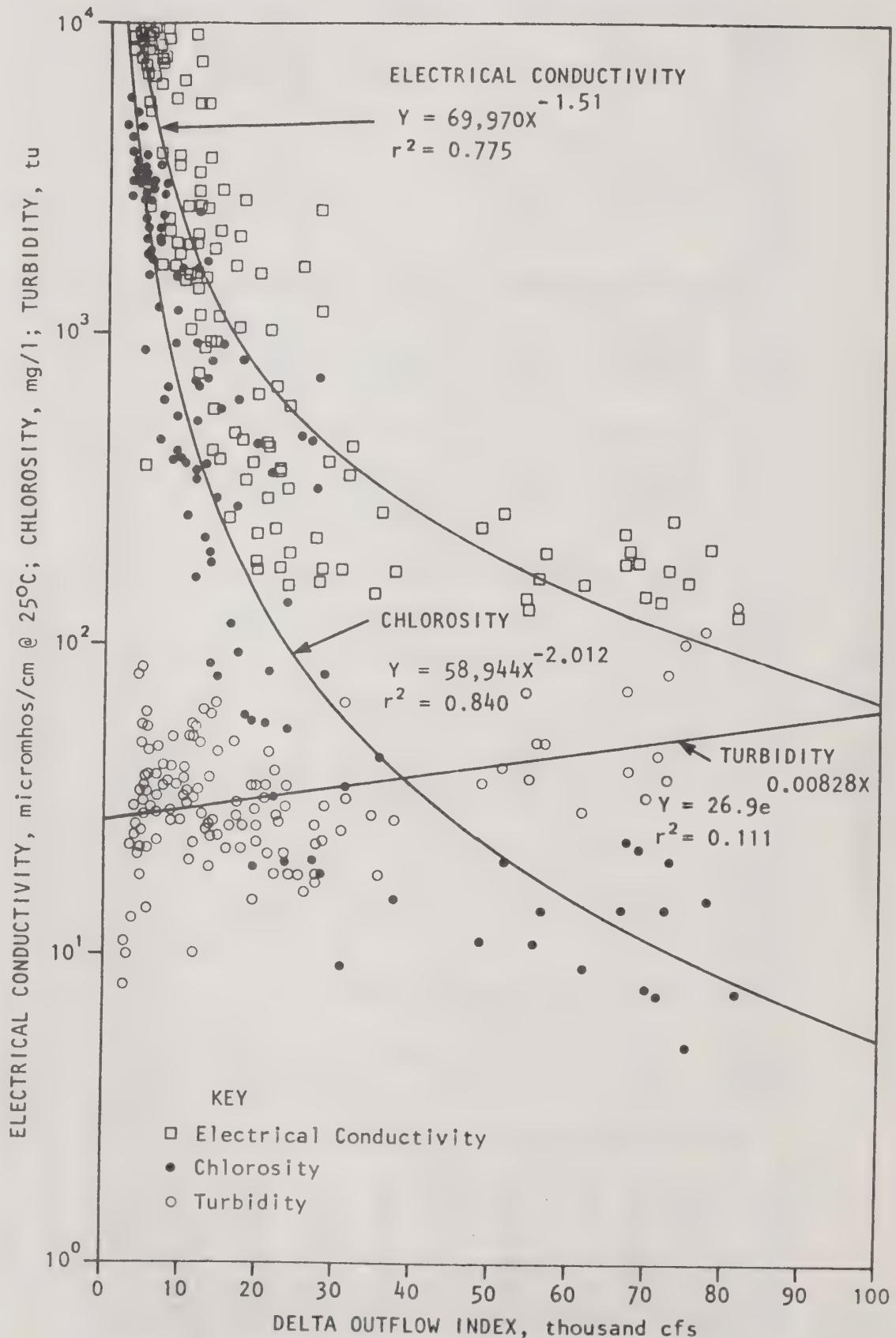
SUMMARY OF HISTORICAL ANNUAL WATER QUALITY OF DELTA OUTFLOW  
SACRAMENTO RIVER AT CHIPPS ISLAND<sup>a</sup>  
Water Year

III-49

Parameter	1968-1969	1969-1970	1970-1971	1971-1972	1972-1973	1973-1974	1974-1975	1975-1976
Ammonia-N, mg/l								
Range	-	-	0.0-0.18	0.005-0.11	0.02-0.11	0.01-0.09	-	-
Mean	-	-	0.032	0.045	0.059	0.038	-	-
Standard Dev.	-	-	0.060	0.035	0.023	0.024	-	-
Nitrate-N, mg/l								
Range	-	-	0.0-0.30	0.02-0.48	0.03-0.64	0.03-0.35	-	-
Mean	-	-	0.10	0.19	0.28	0.17	-	-
Standard Dev.	-	-	0.11	0.14	0.16	0.09	-	-
Phosphorus, mg/l								
Range	-	-	0.08-0.27	0.06-0.27	0.10-0.25	0.08-0.19	-	-
Mean	-	-	0.14	0.12	0.15	0.12	-	-
Standard Dev.	-	-	0.06	0.06	0.04	0.04	-	-
Silica, mg/l								
Range	8.1-18.0	3.0-18.0	11.0-18.0	5.2-22.0	9.2-19.8	12.8-17.6	11-18.2	10-17
Mean	13.5	11.9	13.9	12.2	14.4	15.5	14.9	13.0
Standard Dev.	3.1	5.4	1.9	4.9	3.0	1.4	2.1	1.9
Outflow, acre feet								
Minimum Month	293,000	319,000	721,000	-	-	-	-	-
Maximum Month	8,917,000	11,898,000	5,199,000	-	-	-	-	-
Total Annual	38,367,000	30,138,000	23,100,000	-	-	-	-	-

Source: California State Department of Water Resources

<sup>a</sup>Three-foot depth.



RELATIONSHIP BETWEEN ELECTRICAL CONDUCTIVITY,  
CHLOROSITY, TURBIDITY, AND DELTA OUTFLOW INDEX  
AT CHIPPS ISLAND

JBGA/DLF/RTC 9/77

FIGURE III-11

pH

During the October 1968 to September 1976 period, the pH of the Delta outflow varied from a low of 6.8 to a high of 8.5 units. During this period, the annual (water year) mean varied from 7.6 to 7.9 with standard deviations ranging from 0.2 to 0.4. There does not appear to be a correlation between pH and Delta outflow.

Electrical Conductivity

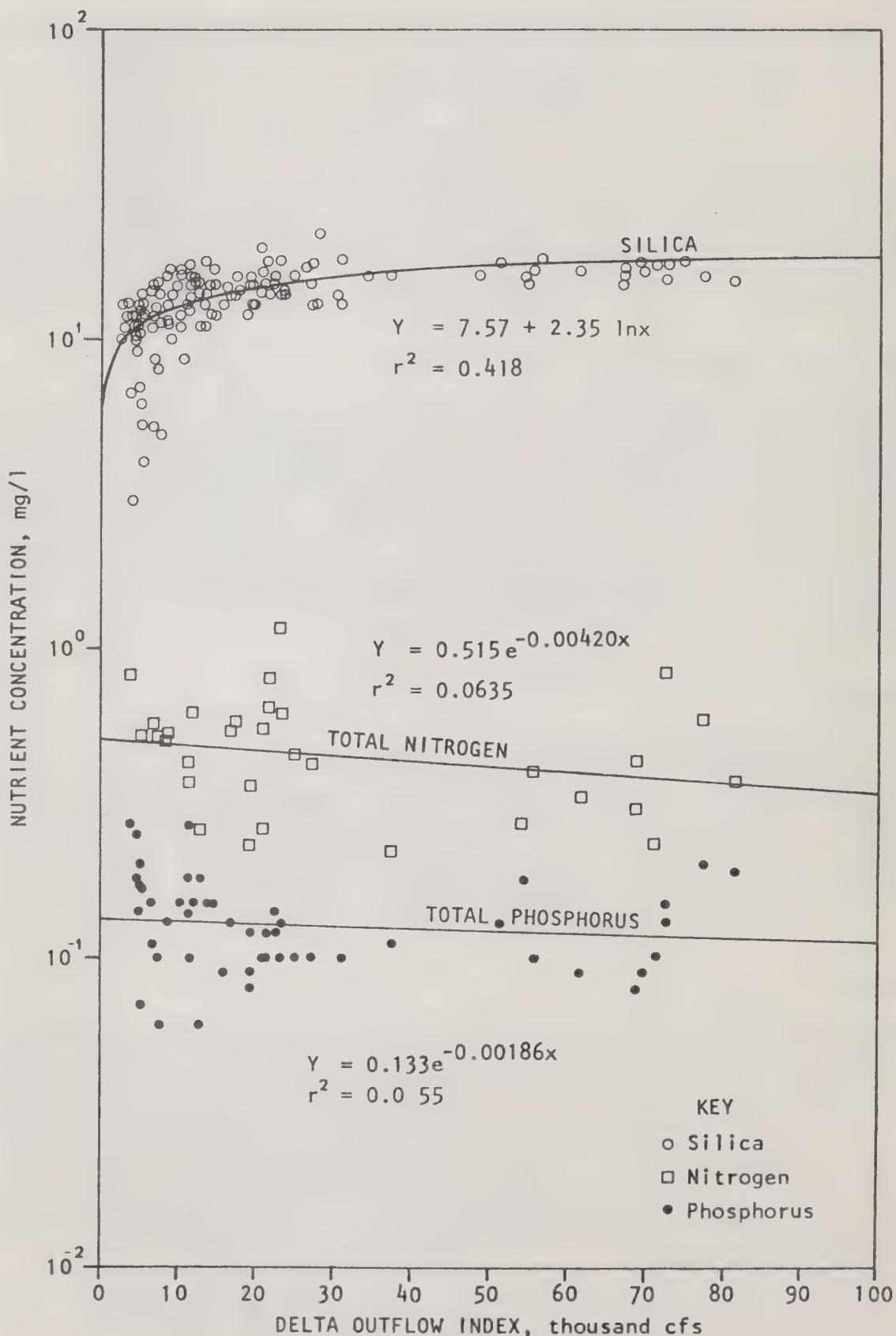
Since the flow past Chipps Island is influenced by tidal action, the electrical conductivity varies considerably. During the October 1968 to September 1976 period, the electrical conductivity varied from a low of 125 to a high of 12,700 micromhos/centimeter at 25°C. The higher fresh water outflows are associated with the lower electrical conductivity values. The relationship between electrical conductivity and the Delta Outflow Index, as shown on Figure III-11, is statistically significant at the 95% level of confidence.

Chloride

Chloride concentrations, like electrical conductivity, vary considerably, depending on tidal action. During the October 1968 to September 1976 period, the chloride concentration in the Sacramento River at Chipps Island varied from a low of 5 mg/l to a high of 4,670 mg/l. The correlation between the Delta Outflow Index and its chloride concentration, as shown on Figure III-11, is statistically significant at the 95% level of confidence.

Nitrogen

Three forms of nitrogen have been analyzed and reported; namely, organic nitrogen, ammonia, and nitrate. During the eight-year study period, nitrogen data were reported only during the October 1970 to June 1974 period. During that period the ranges were 0.16 to 1.10 mg/l as N, 0.0 to 0.18 mg/l as N, and 0.0 to 0.64 mg/l as N, for organic nitrogen, ammonia, and nitrate, respectively. According to the limited data available, as shown on Figure III-12, it does not appear that any statistically significant correlation exists between nitrogen concentrations and the Delta Outflow Index.



RELATIONSHIP BETWEEN NUTRIENT CONCENTRATION  
AND DELTA OUTFLOW INDEX AT CHIPPS ISLAND  
JBGA/DLF/RTC 9/77

FIGURE III-12

### Phosphorus

Phosphorus data were also limited to the October 1970 to June 1974 period. During that period, the total phosphorus concentrations varied from a low of 0.06 to a high of 0.27 mg/l. The annual (water year) mean values were approximately constant (0.12 to 0.15 mg/l with standard deviations of 0.04 to 0.06 mg/l) during this four-year period. As with nitrogen, as shown on Figure III-12, it does not appear that any statistically significant correlation exists between phosphorus concentrations and the Delta Outflow Index.

### Silica

During the October 1968 to September 1976 period, the silica concentrations varied from a low of 3.0 mg/l to a high of 22.0 mg/l. The annual (water year) means, however, were fairly constant as they only varied from 11.9 mg/l to 15.5 mg/l. As shown on Figure III-12, there is a statistically significant correlation between silica concentrations and the Delta Outflow Index at the 95% level of confidence.

## WATER MANAGEMENT PRACTICES

### Upstream Regulation

Major upstream regulation of Delta inflow began in 1944 with the completion of the first units of the Central Valley Project, i.e., Shasta Dam and Reservoir. Since that time, stream flows into the Delta have continued to be modified by upstream storage, diversion, and import developments on the Sacramento and San Joaquin rivers. These projects are listed in Tables III-3 and III-4 and depicted on Figure III-2. Brief descriptions of those facilities which greatly affect Delta inflow follow.

Shasta Division of the Central Valley Project. The Shasta Division of the Central Valley Project consists of Shasta Dam, Reservoir, and Power Plant as well as Keswick Dam, Reservoir, and Power Plant. Shasta Dam, a curved concrete structure with a height of 602 feet and a crest length of 3,460 feet, creates Shasta Lake with a storage capacity of 4.552 million acre-feet. Keswick Dam, a concrete structure with a height

of 159 feet and a crest length of 1,046 feet, creates a small reservoir (24,000 acre-feet capacity) used as an afterbay for Shasta and Trinity river developments.

Trinity River Division of the Central Valley Project. The Trinity River Division of the Central Valley Project contains four dams and reservoirs, three power plants, two tunnels, and a siphon. Surplus Trinity River water is stored, regulated, and diverted into the Sacramento River just upstream of Keswick Dam. Total storage capacity of the Trinity River facilities, i.e., Clair Engle, Lewiston, Whiskeytown, and Spring Creek reservoirs, is about 2.710 million acre-feet.

Folsom Unit of the Central Valley Project. The Folsom Unit of the Central Valley Project consists of Folsom Dam, Lake, and Power Plant on the American River. Folsom Dam, which has a 340-foot high concrete section with a crest length of 1,400 feet flanked by earthfill wing dams on both abutments, creates Folsom Lake with a total storage capacity of 1.010 million acre-feet. Lake Natoma, seven miles downstream, re-regulates power releases from Folsom and serves as a diversion point for the Folsom South Canal.

Oroville Division of the State Water Project. The Oroville Division of the State Water Project consists of Oroville Dam, Reservoir, and Power Plant plus the Thermalito Diversion Dam, Power Plant, Power Canal, Forebay, and Afterbay as well as the Feather River Fish Barrier Dam and Hatchery. Lake Oroville and the Thermalito facilities are operated under a pumpback operation with releases made back to the Feather River from the Thermalito Afterbay. Oroville Dam, a 770-foot high earthfill structure, creates Lake Oroville which has a gross storage capacity of 3.538 million acre-feet.

Friant Division of the Central Valley Project. The Friant Division of the Central Valley Project consists of Friant Dam and Millerton Lake on the San Joaquin River as well as the Friant-Kern and Madera canals. Millerton Lake, with a storage capacity of 520,500 acre-feet, provides storage for future use in Madera, Fresno, Tulare, and Kern counties.

Solano Project. The U. S. Bureau of Reclamation's Solano Project consists of Monticello Dam and Lake Berryessa on Putah Creek, the Putah Diversion Dam, and Putah South Canal.

Lake Berryessa has a gross storage capacity of 1.602 million acre-feet. Water developed by this project is presently being used in Solano and Napa counties.

Mokelumne Project. The East Bay Municipal Utility District has developed the waters of the Mokelumne River by constructing Pardee and Camanche reservoirs and the Mokelumne Aqueduct which transports water to terminal reservoirs in western Contra Costa and Alameda counties.

Hetch Hetchy Project. The City and County of San Francisco has developed the Tuolumne River watershed by constructing three reservoirs (Hetch Hetchy, Lake Eleanor, and Lake Lloyd) and the Hetch Hetchy Aqueduct which extends some 135 miles from the Tuolumne River to Crystal Springs Reservoir in San Mateo County. In addition, the City is participating in the yield of New Don Pedro Reservoir with the Modesto and Turlock irrigation districts.

### Export Entitlements

Several agencies presently operate export facilities within the Sacramento-San Joaquin Delta. By far the largest volumes of water are exported by the U. S. Bureau of Reclamation's Central Valley Project and the State Water Project, the latter operated by the California Department of Water Resources. Lesser volumes are taken by the City of Vallejo and the Contra Costa Canal. The present total annual export from the Delta is about five million acre-feet per year and is expected to increase to over eight million acre-feet per year by the year 2010. A summary of estimated annual and future amounts of water to be diverted from the Delta is presented in Table III-13.

### Intra-Delta Entitlements

The internal Delta water requirements are based on five distinct categories of use:

1. Channel depletion in the Delta lowlands, i.e., direct diversions and seepage from Delta channels;
2. Consumptive use in the Delta uplands which obtain their water supply almost exclusively by diversions from Delta channels;

TABLE III-13

ESTIMATED ANNUAL AMOUNTS OF WATER  
EXPORTED FROM THE DELTA

Year	Export Volume, acre-feet		
	Central Valley Project	State Water Project	Total Export
1971-72 <sup>a</sup>	-	-	3,495,000
1972-73 <sup>a</sup>	-	-	3,438,000
1973-74 <sup>a</sup>	-	-	4,410,000
1974-75 <sup>a</sup>	-	-	3,935,000
1975-76 <sup>a</sup>	-	-	4,995,000
1980	2,180,300	3,449,000	5,629,000 <sup>b</sup>
1990	3,579,300	3,742,000	7,321,300 <sup>b</sup>
2000	3,921,000	3,842,000	7,754,000 <sup>b</sup>
2010	4,133,400	3,953,000	8,086,400 <sup>b</sup>
2020	4,353,900	4,087,000	8,440,900 <sup>b</sup>

Sources: (1971-76) California Department of Water Resources  
Memorandum, 1977  
(1980-2020) California Department of Water Resources,  
Peripheral Canal Project Draft EIR, August 1974

<sup>a</sup>Year is a water year, i.e., October to following September.

<sup>b</sup>Includes Central Valley Project and State Water Project diversions only.

3. Contra Costa Canal diversions;
4. Offshore supply to municipalities and industries in the Western Delta; and
5. Delta outflow required for salinity repulsion.

As part of its deliberations in adopting its Delta Water Rights Decision 1379, the State Water Resources Control Board estimated the net annual Delta water requirements during a normal year as follows:

Delta lowlands channel depletion	1,266,000 acre-feet
Delta uplands consumptive use	340,000 acre-feet
Contra Costa Canal diversions	83,000 acre-feet
Offshore municipal and industrial supply	40,000 acre-feet
Net Delta outflow requirement	<u>2,893,000 acre-feet</u>
Total	4,622,000 acre-feet

During a critical year, the net Delta outflow requirement would only be 2,376,000 acre-feet. Therefore, during those years the net Delta requirement would be 4,105,000 acre-feet.

#### Delta Outflow

The net outflows required for the Delta (estimated net flows at Chipps Island) depend principally on the level at which the Delta uses are protected and the hydrologic condition at that time. In order to comply with the State Water Resources Control Board's Decision 1379 which was adopted in 1971, the Central Valley Project and the State Water Project would have to be operated to maintain the following net Delta outflows during a normal year:

Municipal and Industrial	150 days @ 6,200 cfs = 1,860,000 acre-feet
Fish and Wildlife	35 days @ 4,400 cfs = 308,000 acre-feet
Agricultural (Blind Point)	55 days @ 2,500 cfs = 275,000 acre-feet
Agricultural (Resolution 68-17)	125 days @ 1,800 cfs = <u>450,000 acre-feet</u>
Total	2,893,000 acre-feet

Although the protection contemplated for agricultural use will be for longer periods than the 180 days indicated, the remaining protection will occur during the time when higher flows are provided for other uses.

Due to less stringent criteria during a critical year, the net Delta outflow requirements are also reduced as shown below:

Municipal and Industrial	100 days @ 6,200 cfs = 1,240,000 acre-feet
Fish and Wildlife	35 days @ 4,400 cfs = 308,000 acre-feet
Agricultural	230 days @ 1,800 cfs = <u>828,000 acre-feet</u>
Total	2,376,000 acre-feet

## REGULATORY REQUIREMENTS

Criteria for the control of salinity intrusion in the Western Delta have been established under California law by the State Water Resources Control Board and its predecessors in the administration of water rights for the Central Valley Project and the State Water Project. Unlike most water quality standards that are enforced by waste discharge controls, effecting these criteria requires the release of fresh water from project reservoirs during the drier months of most years. In the interior Delta, criteria have also been established to dilute the natural concentration of salts which is due to the use and reuse of water in and upstream of the Delta. Release of stored water from project reservoirs may also be required to meet these latter criteria which will have a direct effect on Delta outflow.

Table III-14 summarizes Delta water quality standards that are directly related to water project management and Delta outflow. Major criteria documents are described in the following paragraphs, and associated Delta locations are shown on Figure III-1.

### November 19, 1965, Delta Water Quality Criteria

On November 19, 1965, the Sacramento River and Delta Water Association, San Joaquin Water Rights Committee, California Department of Water Resources, and U. S. Bureau of Reclamation approved a set of Delta water quality criteria as an appropriate basis for further negotiations leading to agreements between Delta interests and operators of the State and Federal projects. The objectives of these criteria were to: (1) protect the Western Delta channels against the intrusion of ocean salinity and (2) provide water of suitable quality in the interior Delta channels acceptable for agricultural uses.

Briefly, these criteria provide for a quality of water in the Sacramento River at Emmaton and the San Joaquin River at Jersey Point that does not exceed 1,000 parts per million (ppm) chlorides when measured on the basis of the average mean daily value for any 10 consecutive days. The criteria also allow a relaxation in critical years during August through December when the quality criteria set forth above may be increased to 1,400 ppm. The criteria also provide for spring-time flushing flows to prevent the quality of water from exceeding an average mean daily chloride content of 200 ppm for a period of at least 10 consecutive days during the period April 1 through May 31 except

TABLE III-14

**SUMMARY OF DELTA SALINITY AND ENVIRONMENTAL CRITERIA  
RELATED TO WATER DEVELOPMENT IN THE DELTA AREA**

USE PROTECTION		STATION	TYPE OF YEAR 1/	PERIOD	PARAMETER2/	CRITERIA DOCUMENTS <sup>3/</sup> (Criteria designated by Article number)						
						NOVEMBER 18, 1965 (LWP-SNP)	DECISION 1275- 1291 (SNP) 1967	STATE WATER QUALITY CONTROL POLICY, 1967	SMCA RESOLUTION 68-17, 1968	SECRETARY OF INTERIOR (LWP) 1968	DECISION 1379 (SPP-CPU) 1971	DECISION 73-16, 1973
Western Delta Agriculture	Without substitute (overland) supply	Jersey Point and Emleton	N C L	Jan-Dec Jan-Jul Aug-Dec	1000 ppm Cl <sup>-</sup> (10-DA) 1000 ppm Cl <sup>-</sup> (10-DA) 1400 ppm Cl <sup>-</sup> (10-DA)	D-1	D-1		B-1			
		Blind Point	NC NC C	Apr-Jul Aug-Dec Apr-Dec	350 ppm Cl <sup>-</sup> (14-DA) 1000 ppm Cl <sup>-</sup> (14-DA) 1000 ppm Cl <sup>-</sup> (14-DA)						A-1	
	With substitute (overland) supply	Three-mile Sl @ Sac and San Joaquin R (after 1980)	N C L	Jan-Dec Jan-Jul Aug-Dec	1000 ppm Cl <sup>-</sup> (10-DA) 1000 ppm Cl <sup>-</sup> (10-DA) 1400 ppm Cl <sup>-</sup> (10-DA)	E	E					
		Jersey Point and Emleton	NC MC C	Apr-Jul Aug-Dec Apr-Dec	350 ppm Cl <sup>-</sup> (14-DA) 1000 ppm Cl <sup>-</sup> (14-DA) 1000 ppm Cl <sup>-</sup> (14-DA)						A-1	
Delta Agriculture (flushing)	Jersey Point and Emleton	N, NM	Apr-May		200 ppm Cl <sup>-</sup> (10-CD)	D-2	D-2		B-2		A-1	
Interior Delta Agriculture	Terminus, Rio Vista, San Andreas Landing, and Clifton Court Ferry	N	Jan-Dec		500 ppm TDS (MA)	D-3b D-4	D-3b D-4	B-3b B-4	A-2 <sup>4/</sup>	A-2 <sup>4/</sup>	A-2 <sup>4/</sup>	
		BN	Jan-Jul		500 ppm TDS (MA)							
		C,D	Aug-Dec Jan-Mar		600 ppm TDS (MA) 500 ppm TDS (MA)							
			Apr-Dec		600 ppm TDS (MA)							
	Bifurcation of Middle & Old R				Same as above stations after initial operation of the Peripheral Canal	D-3b D-4	D-3b D-4	B-3b B-4				
	Sacramento R @ Green's Landing (adjustment)				Whenever values exceed 150 ppm TDS (MA), max values for above stations may be increased by adding 1.5 times the excess	D-5	D-5		B-5		A-2 <sup>4/</sup>	
	Clifton Court Ferry	All	Jan-Dec		600 ppm TDS (MA)			16a				
	Eastern Delta channels	All	Jan-Dec		700 ppm TDS (MA)			16e				
Agriculture, Municipal and Industrial	Vermont	All	Jan-Dec		500 ppm TDS (MA)	C <sup>8/</sup>	C <sup>8/</sup>	16d				
Contra Costa Canal Municipal and Industrial	Rock Slough @ Contra Costa Canal Intake	All	Jan-Dec		250 ppm Cl <sup>-</sup> (MTC) & 100 ppm Cl <sup>-</sup> (MTC) at least 65% of yr			17a 16c		B-1 <sup>4/</sup>		
					750 ppm TDS (MTC) & 380 ppm TDS (MTC) at least 65% of yr							
Vallejo Municipal and Industrial	Cache Sl @ City of Vallejo Intake	All	Jan-Dec		250 ppm TDS (AT) 100 ppm Cl <sup>-</sup> (AT)			16b 17b				
Western Delta Municipal and Industrial without substitute (overland)	Antioch	N, NM D C	150 days 120 days 100 days		450 ppm TDS (10-DA) 450 ppm TDS (14-DA)					B-5 <sup>6/</sup>	B-2	A-1
	Blind Point	All	Apr-Jun		250 ppm Cl <sup>-</sup> (MSZS)		15 <sup>7/</sup>					
	Above Three-mile Sl to Sacramento R & between Jersey Pt & Venice Isl in San Joaquin & Pulse R	N			Until initial operation of Peripheral Canal, 350 ppm TDS (DA) from April 1 until water temperature reaches 60° F; thereafter, 180 ppm TDS (DA) for five weeks					B-2 <sup>6/</sup>		
Striped Bass	Antioch Water Works Intake	All	For 3 weeks beginning when water temperature reaches 60° F		1000 ppm TDS (14-DA)					C-1a	A-2 <sup>7/</sup>	
	Prisoner's Point				350 ppm TDS (14-DA)							
	Export pumping	All	Apr 25-May 31		Minimize export					C-1b		
Neomysis	Chippie Island	All	Jan-Dec		4000 ppm Cl <sup>-</sup> (14-DA)					C-1c		
Salmon and Steelhead	Principal channels of the Sacramento-San Joaquin Delta	All	Jan-Dec		Positive downstream flow; 95% salvage of diverted salmon and steelhead					C-2a C-2b		
	Southern and Eastern Delta	All	Sep-Nov		Predominantly San Joaquin River flow					C-2b		
Duck Food - Suisun Marsh	Suisun Marsh	All	Apr 15-Jun 1		9000 ppm TDS average (last 12" of soil)					C-3a		
			Jan-Dec (without alternate supply)		18000 ppm TDS (MA) in surrounding Bay and channels							

1/ N-Normal; NB-Below Normal; C-Critical; MC-Most Critical; D-Dry.

2/ ppm parts per million; Cl<sup>-</sup>=Chlorides; TDS=Total Dissolved Solids; (10-DA)=10-day average; (10-CD)=Daily average for at least 10 consecutive days;

(14-DA)=14-day average; (MA)=Monthly average; (MTC)=Mean Tidal Cycle; (AT)=All Times; (MSZS)=Maximum Surface Zone Salinity; (DA)=Daily average.

3/ State Water Quality Control Policy (1967), Resolution 68-17 (1968), and Resolution 73-16 (1973) have been adopted as Federal policy. (June 20, 1973).

4/ EC values converted to estimated equivalent TDS values.

5/ Until June 30, 1970. Re-established September 26, 1972 by Water Right Permit numbers 16477 thru 16483.

6/ Until September 30, 1972. Extended on November 2, 1972 to operate within the Project capability.

7/ May be modified for fishery experiments.

8/ Provided not more than 70,000 AF released from New Melones Reservoir for water quality control.

in dry or critical years. In addition, the November 19, 1965, criteria specify total dissolved solids limits at specific locations for the interior Delta channels (e.g., Sacramento River at Rio Vista, San Joaquin River at San Andreas Landing, Little Potato Slough at Terminous, and Old River at Clifton Court Ferry) that are intended to assure adequate quality irrigation water.

State Water Rights Board Decision D 1275

On May 31, 1967, after 40 days of hearings, the State Water Rights Board, predecessor of the State Water Resources Control Board, adopted Decision D 1275 concerning eight applications of the California Department of Water Resources to appropriate water from the Feather River, Sacramento-San Joaquin Delta, Italian Slough, Lindsey Slough, and San Luis Creek. These eight applications were related to operation of the State Water Project.

During the hearings on these applications, over 100 protests were filed. The primary and most controversial issues raised were: (1) What quantity of unappropriated water is available in the Delta to supply the Department? and (2) What quality of water in the Delta should be maintained to protect prior rights?

The Board found that these issues were interrelated, and an analysis of the quantity of water available had to take into consideration the quality to be maintained. The Board found, however, that sufficient information was not available to finally determine the terms and conditions regarding water quality in the Delta which would reasonably protect vested rights without resulting in waste of water. Therefore, the Board directed the Department to program its operations to comply with the following:

1. Until further order of the Board, permittee shall make no diversions and shall not collect water to storage during the period April 1 through June 30 at any time the maximum surface zone chloride ion content of the San Joaquin River at Blind Point exceeds 250 ppm.
2. Until further order of the Board, these permits shall be subject to the water quality criteria included in the November 19, 1965, Delta Water Quality Criteria.

In addition, the Board limited the season of diversion to storage to the period October 1 of each year to July 1 of the succeeding year.

State Water Rights Board Decision D 1291

Petitions for reconsideration of Decision D 1275 were filed by the Central Valley Regional Water Quality Control Board on June 29, 1967, and by the Contra Costa County Water Agency and Department of Water Resources on June 30, 1967. The U. S. Bureau of Reclamation also filed a request that a hearing be held pursuant to the Department's petition. The petitions of the Central Valley Regional Water Quality Control Board and the Contra Costa County Water Agency were denied by the Board. However, the Department's petition was granted for limited purposes.

Following a hearing on August 22, 1967, the State Water Rights Board adopted Decision D 1291 on November 30, 1967, which amended its Decision D 1275. Basically, the amendments extended the season of diversion to storage. For the Feather River, the season of diversion to storage was to include the period from about September 1 of each year to about July 31 of the succeeding year. For the Delta channels and San Luis Creek, the season of diversion to storage was to include the period from January 1 to December 31 of each year.

Water Quality Control Policy for Sacramento-San Joaquin Delta

Delta water quality standards for compliance with the Federal Water Quality Act of 1965 were first proposed by the Central Valley Regional Water Quality Control Board in April 1967. On June 14, 1967, the State Water Quality Control Board heard comments on the proposed standards and, after eliminating criteria related to control of salinity intrusion, adopted as State policy the standards as proposed by the Regional Board.

However, the Federal Water Pollution Control Administration (FWPCA) informed the newly created State Water Resources Control Board that the State policy did not adequately protect all the beneficial uses identified in that policy. The FWPCA also offered for consideration supplemental chloride and total dissolved solids criteria which were similar to the November 19, 1965, criteria except for two additional criteria related to striped bass spawning and municipal and industrial use without a substitute supply (see Table III-14).

State Water Resources Control  
Board Resolution No. 68-17

On October 28, 1968, the State Water Resources Control Board adopted Resolution 68-17 which adopted supplemental water quality objectives for the Sacramento-San Joaquin Delta. These supplemental objectives were the same as Articles C and D of the November 19, 1965, criteria which specified chloride and total dissolved solids standards for the Delta channels (see previous discussion).

State Water Resources Control Board Decision 1379

On July 22, 1969, the State Water Resources Control Board reopened hearings to consider what further conditions should be imposed in the water rights terms for the State Water Project and the Central Valley Project. On July 28, 1971, after 93 days of actual hearings and 11,000 pages of testimony, the State Board adopted its Delta Water Rights Decision 1379.

The record shows that the quantity needs of almost all of the Delta users are met almost all the time, and depletion of inflow will not affect this availability. With the exception of periods of extraordinary low tides, at which time the southeast portion of the Delta is particularly affected, water is generally available at the intakes of the numerous pumps of Delta users. However, the quality of the water at the pump intakes is not always suitable for the uses intended, nor is it always suitable for spawning of striped bass, maintenance of a good population of the principal food of juvenile striped bass (the opossum shrimp, Neomysis awatchensis), maintenance of an adequate food supply for migratory water fowl in the Suisun Marsh area, or passage of salmon.

Therefore, the Board found that quantitative determinations of the extent of vested rights was meaningless. The measure of a water rights entitlement in the Delta is the quality of the entitlement.

The standards which the Board established in Decision 1379 are known as the State Delta Standards. According to the Board's findings, these standards are necessary and proper to provide reasonable protection for all beneficial uses in the Delta, and they are in the public interests. The standards are summarized as follows:

1. Protection of municipal, industrial, and agricultural uses including the needs of the Suisun Marsh and the fisheries food chain by limits on electrical conductivity (which correlates with total dissolved solids) in Old River at Clifton Court Ferry, Rock Slough at Contra Costa Canal Intake, South Fork of the Mokelumne River near Terminous, Sacramento River at Rio Vista, and San Joaquin River at San Andreas Landing and chloride limits in the Sacramento River at Emmaton and in the San Joaquin River at Jersey Point, Blind Point, and Antioch;
2. Protection of striped bass spawning by limits on electrical conductivity in the San Joaquin River at Antioch Water Works Intake and at Prisoners Point; and
3. Protection of fish and wildlife through imposition of criteria at certain points in the Delta.

State Water Resources Control  
Board Resolution No. 73-16

Approval of the "Supplemental Water Quality Control Policy for the Sacramento-San Joaquin Delta" (SWRCB Resolution No. 68-17) by the Secretary of the Interior (as then required by the Federal Water Pollution Control Act) was conditioned on the Board's commitment to adopt additional salinity objectives when sufficient information became available.

On December 20, 1972, the State Board held a public hearing to receive comments and information concerning proposed salinity objectives for the protection of striped bass and other beneficial uses of water in the Western Delta. Subsequently, on April 19, 1973, the State Board adopted Resolution No. 73-16 which adopted salinity objectives for the protection of striped bass and municipal and industrial water supplies in the Western Delta (see Table III-14).

Water Quality Control Plan Reports

Early in 1972 the State Water Resources Control Board and the nine California Regional Water Quality Control Boards commenced the second phase of a comprehensive planning effort that resulted in the development of water quality control plans for the entire

State. The basic purpose of these plans was to determine the future direction of water quality control for protection of all of California's waters. These plans satisfied four objectives as follows:

1. The plans were a requirement of the U. S. Environmental Protection Agency in the allocation of Federal grants to cities and districts for construction of wastewater treatment facilities.
2. The plans fulfilled the requirements of the Porter-Cologne Water Quality Control Act for water quality control plans.
3. The plans provided a basis for establishing priorities in disbursement of both State and Federal grants for the construction or upgrading of wastewater treatment facilities.
4. The plans, by delineating water quality objectives to be achieved and maintained, provided the basis for establishment or revision of waste discharge permits by the Regional Boards.

Two of these plans--Sacramento-San Joaquin Delta Basin (5B) and San Francisco Bay Basin (2)--apply to the study area.

Sacramento-San Joaquin Delta Basin (5B). The Sacramento-San Joaquin Delta Basin (5B) Water Quality Control Plan was adopted by the California Regional Water Quality Control Board, Central Valley Region, and subsequently approved by the State Water Resources Control Board on August 21, 1975. This plan contains general water quality objectives for oil and grease, pH, pesticides, radioactivity, sediment, settleable material, suspended material, tastes and odors, temperature, toxicity, and turbidity. In addition, specific salinity objectives were included which are basically the same as those contained in the State Water Resources Control Board's Decision 1379.

San Francisco Bay Basin (2). The San Francisco Bay Basin (2) Water Quality Control Plan was adopted by the California Regional Water Quality Control Board, San Francisco Bay Region, and subsequently approved by the State Water Resources Control Board on April 17, 1975. This plan also

contains general water quality objectives for various parameters. In addition, specific salinity objectives at Chipps Island and in Suisun Marsh were included which are basically the same as those contained in the State Board's Decision 1379.

State Water Resources Control Board Resolution No. 77-6

On January 20 and 21, 1977, the State Board held hearings to discuss how best to cope with the drought that was well into its second year. Subsequently, the Board adopted Resolution No. 77-6 which adopted the "Interim Water Quality Objectives for Calendar Year 1977." These interim water quality objectives for the Delta and Suisun Marsh were intended to help mitigate the impact of the drought and to spread the resulting burdens of a critically short water supply as broadly as possible while providing adequate protection to beneficial uses within the Delta. Also, the interim objectives were developed to assist in the maintenance of as much carry-over storage as possible in upstream reservoirs in the fall of 1977 to protect against the possibility of another very dry year in 1978.

Three main objectives affect the net Delta outflow, namely:

1. Maximum chloride concentration of 1,000 mg/l in the Sacramento River at Emmaton during the period January 1 through March 31;
2. Maximum chloride concentration of 250 mg/l in the San Joaquin River at Blind Point during the period April 1 through September 30; and
3. Maximum electrical conductivity of 15.6 millimhos in the Sacramento River at Chipps Island during the period October 1 through December 31.

The required net Delta outflows to meet these objectives are as follows:

Jan 1-Mar 31	90 days @ 2,500 cfs =	446,000 acre-feet
Apr 1-Sep 30	183 days @ 3,100 cfs =	1,125,000 acre-feet
Oct 1-Dec 31	92 days @ 3,500 cfs =	<u>639,000 acre-feet</u>
Total		2,210,000 acre-feet

This relaxed net Delta outflow is about 76 percent of that required by Decision 1379 which requires an annual net Delta outflow of 2,893,000 acre-feet.

#### Four-Agency Fish Agreement

The U. S. Bureau of Reclamation, U. S. Fish and Wildlife Service, California Department of Water Resources, and California Department of Fish and Game have proposed a Memorandum of Agreement (revised draft April 12, 1977) with respect to operation of the Central Valley Project and the State Water Project. The Four-Agency Fish Agreement states:

"To the extent that the Projects (CVP and SWP) affect fish and wildlife resources in the Estuary, the Projects shall be operated to achieve the following goals:

1. Restore and maintain adult populations of fish and wildlife on the average at the Historical Level.
2. Realize the Projects' potential for increasing these resources above Historical Levels consistent with other Project purposes."

The Agreement contains very specific water quality and flow standards to realize the above goals. Basically, the standards are designed to protect striped bass spawning, striped bass survival and neomysis protection, upstream and downstream migration of salmon, and the Suisun Marsh.

## CHAPTER IV

### DELTA OUTFLOW-BAY ENVIRONMENTAL QUALITY RELATIONSHIPS

#### PREDICTED FUTURE OUTFLOWS

Meeting future water demands of California agriculture, industry, and municipalities is believed to require both the construction of more reservoirs for the capture and storage of winter runoff and increased export of water from the Delta. Both will reduce Delta outflow to the Bay. The California Department of Water Resources most recent estimates of future Delta outflows in 1990 are 8.98 million acre-feet in a normal year; 2.25 million acre-feet in a dry year; and 32.95 million acre-feet in a wet year. Under historic conditions, these corresponding flows would have been 25.92 million acre-feet, 4.80 million acre-feet, and 53.01 million acre-feet, respectively.

Since the 1921-22 water year, Delta outflows of less than 8.98 million acre-feet have occurred only seven times (4.73 in 1923-24, 8.58 in 1928-29, 4.83 in 1930-31, 8.49 in 1932-33, 8.58 in 1933-34, 8.06 in 1938-39, and 6.08 in 1975-76). The lowest historic Delta outflow was 4.73 million acre-feet in 1923-24, more than twice the predicted 1990 Delta outflow during a dry year.

A summary of Delta outflows over time is presented in Table IV-1 for four different types of water years. The estimated future flows were derived from two operations studies being conducted by the Department of Water Resources for use in Phase 2 of the State Water Resources Control Board's Delta hearings. Both of these studies assume that the draft "Four-Agency Fish Agreement" would apply to Delta outflow. The 1980 level does not assume any additional Delta transfer facilities; however, the 1990 level assumes completion of North and South Delta Transfer Facilities plus a groundwater storage project south of the Delta yielding 400,000 acre-feet of firm supply annually. Normal year Central Valley Project and State Water Project Delta exports were assumed to be about 6.44 million acre-feet in 1980 and about 7.48 million acre-feet in 1990.

TABLE IV-1

SUMMARY OF DELTA OUTFLOW OVER TIME  
(mean cfs)

	Fall (Oct-Dec)	Winter (Jan-Mar)	Spring (Apr-Jun)	Summer (Jul-Sep)	Annual Average (Water Year)
Normal Year (1935-36)					
Historical Conditions	9,040	86,000	46,100	2,790	35,800
1970 Development	9,760	60,600	18,600	7,730	23,900
1980 Development <sup>1</sup>	6,710	45,900	13,900	5,900	17,500
1990 Development <sup>2</sup>	3,300	31,600	10,600	4,370	12,400
Dry Year (1930-31)					
Historical Conditions	8,220	17,000	3,550	-1,920	6,630
1970 Development	8,330	10,600	3,490	8,930	7,870
1980 Development <sup>1</sup>	3,780	4,780	3,560	3,510	3,900
1990 Development <sup>2</sup>	3,290	2,960	3,080	3,100	3,110
Wet Year (1937-38)					
Historical Conditions	43,900	134,000	105,000	11,300	73,200
1970 Development	42,400	112,000	72,300	11,900	59,200
1980 Development <sup>1</sup>	30,100	110,000	62,900	8,640	52,600
1990 Development <sup>2</sup>	18,800	103,000	55,600	6,310	45,500
Long-Term Average (1922-71)					
Historical Conditions	19,600	56,900	37,200	4,940	29,500
1970 Development <sup>3</sup>	17,400	44,000	20,200	8,490	22,400
1980 Development <sup>1</sup>	11,800	37,400	19,200	6,470	18,600
1990 Development <sup>2</sup>	9,120	33,400	16,900	4,580	15,900

Source: DWR (December 16, 1971) and DWR (March 21, 1977)

<sup>1</sup> Assumes 4-Agency Fish Agreement Criteria and Delta exports of 6.44 maf<sup>2</sup> Assumes 4-Agency Fish Agreement Criteria and Delta exports of 7.48 maf<sup>3</sup> 1922-54 average

It should also be pointed out that the effect of the 1990 level operation study flows on interior Delta water quality has not been tested to date. Therefore, some adjustments in Delta outflow and inflow may be warranted if additional studies reveal interior water quality problems.

As can be seen by examining the data presented in Table IV-1, net Delta outflows in the future will be substantially reduced on an annual (water year) average basis. For example, during a normal year, the annual average Delta outflow will be reduced by the following percentages over historical conditions: 1980 development, 51 percent; and 1990 development, 65 percent.

#### **HYDRAULIC CONSIDERATIONS**

Delta outflows affect the hydraulics of the San Francisco Bay system, especially in the northern reaches. Three hydraulic parameters--advective flow, mixing, and residence time--are briefly discussed in the following paragraphs.

##### **Advective Flow**

USGS studies of circulation in San Francisco Bay show that, in the central and northern parts, the Bay behaves in the classical estuarine manner: outward freshwater flow occurs along the surface and a counter-current of ocean water is induced along the bottom, with gradual mixing effected with the outflowing freshwater.

South of the San Francisco-Oakland Bay Bridge there is relatively little natural stream inflow, so that waste discharges and evaporation can at time become significant in effecting advective flow. During typical summer conditions of high evaporation and low fresh water inflow, the South Bay behaves as a negative estuary; that is, the net advective flow is landward. During wetter winter seasons, higher Delta outflows can cause a fresh or brackish water invasion of the South Bay, which can result in salinity stratification and circulating currents.

##### **Mixing**

Mixing characteristics of the San Francisco Bay estuary are complex and influenced by many factors including the geometry of the estuary, the amplitude and form of the tide, the density structure and the amount of freshwater entering the estuary from

the Delta. The most commonly referred to forms of mixing are turbulent diffusion and dispersion. Turbulent or eddy diffusion represents the mixing that occurs as the result of turbulent properties in homogeneous flow. Dispersion, on the other hand, takes place as a result of velocity variations, either in the vertical or transverse direction. Usually, mixing caused by turbulent diffusion is one or two orders of magnitude less than that induced by dispersion (Brown and Caldwell, et al., 1974). As a result both causes of mixing are usually referred to as advective dispersion or "flow-induced" mixing.

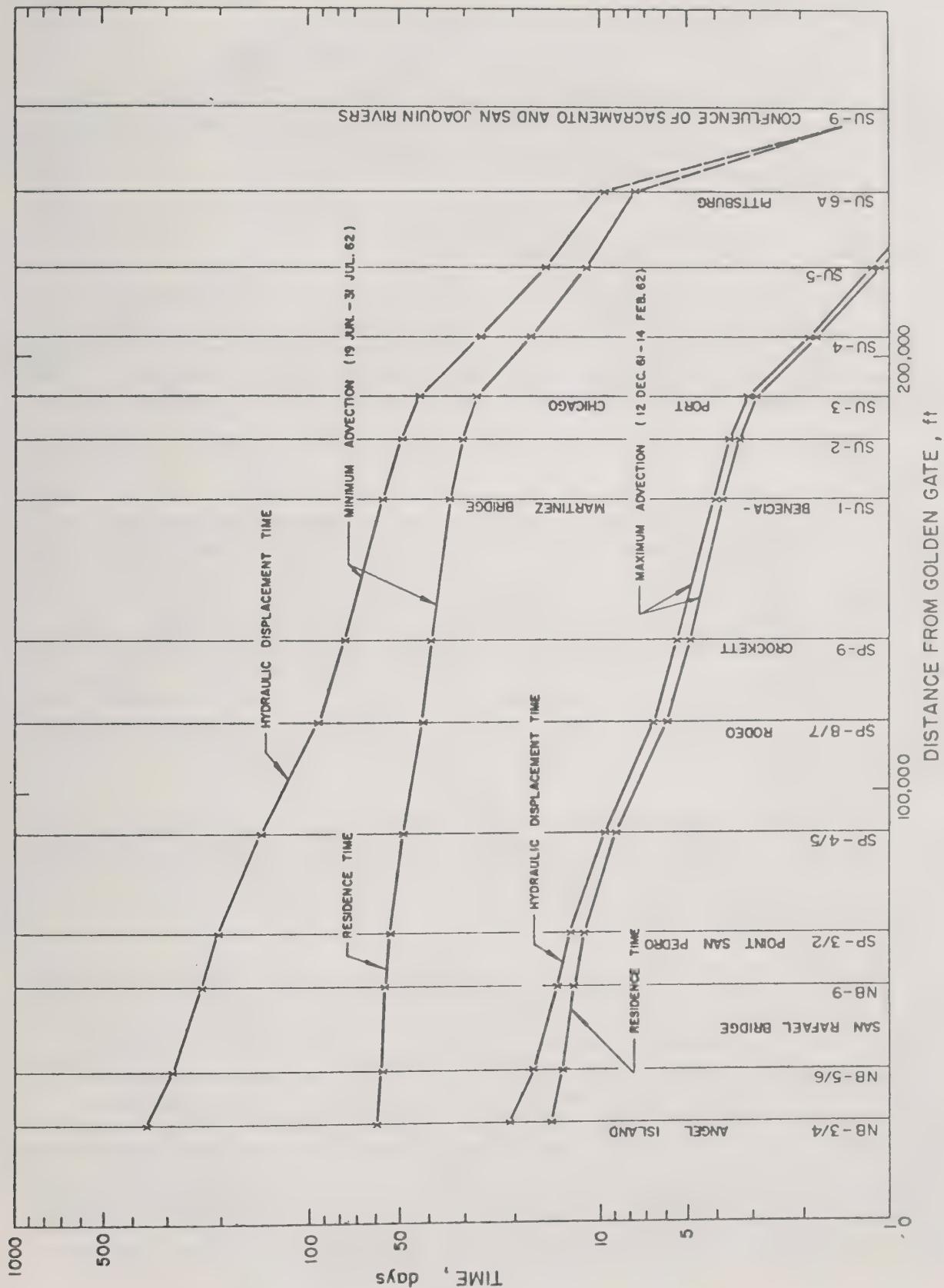
In areas of the Bay that are not fully mixed in the vertical, increased mixing in regions with strong salinity gradients usually occurs. In these cases, there is an increase in circulation caused by density differences; this increase in mixing is greatest where the salinity gradient is strongest. This form of mixing is referred to as "density induced." As will be shown later in this section, stratification is dependent upon Delta outflow (Kelley & Tippets, 1977).

A third form of mixing is that induced by tidal action which sets up an oscillating flow and increases the amount of mixing. These oscillating flows increase the vertical and transverse velocity variations. This form of mixing is referred to as "tidally induced." Delta outflow also influences this type of mixing.

#### Residence Times

As part of its Comprehensive Study of San Francisco Bay, the University of California's Sanitary Engineering Research Laboratory calculated mean residence times and hydraulic displacement times for conservative constituents in the northern reach of San Francisco Bay. These calculations were made for low Delta outflows (average Delta Outflow Index value during the period was 3,324 cfs) and high Delta outflows (average Delta Outflow Index value during the period was 15,085 cfs). The results of these calculations are shown on Figure IV-1.

As shown on Figure IV-1, the effect of diffusion is considerable during the low-flow period but not during the high-flow period. For example, the mean residence time of a conservative constituent in San Pablo Bay was about 13 days (the difference between 53 and 40 days on the figure) during the low-flow period, whereas the hydraulic displacement time for the corresponding period was about 120 days (the difference between 200 and 80 days on the figure).



SOURCE: UNIVERSITY OF CALIFORNIA, SERL

RESIDENCE AND HYDRAULIC  
DISPLACEMENT TIME IN NORTHERN REACH  
1961-1962 WATER YEAR  
JBGA/WOM/RTC 10/77

FIGURE IV-1

During the high-flow period, however, the mean residence time and hydraulic displacement time in San Pablo Bay were both about six days. Delta outflow, therefore, has a direct effect on residence times in the northern reach of San Francisco Bay.

#### ENVIRONMENTAL QUALITY CONSIDERATIONS

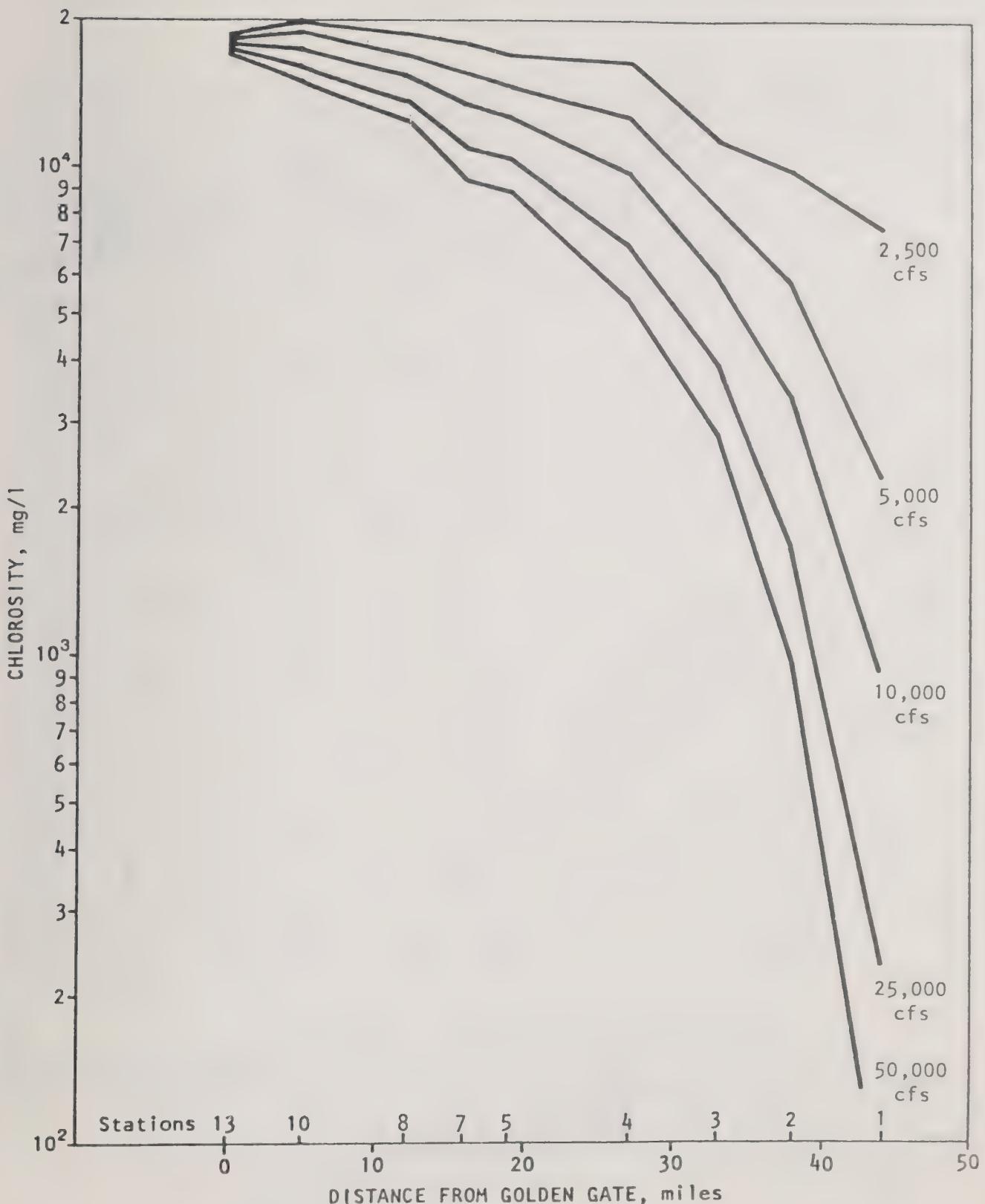
The magnitude of the Delta outflow affects the environmental quality of San Francisco Bay in several ways: (1) it reduces ocean-derived salinity and (2) it is a major source of the essential nutrient supplies and suspended sediments to the Bay. These considerations will be discussed in the following paragraphs.

##### Salinity

Approximately 1.2 million acre-feet of seawater (25 percent of the Bay's total volume) flows in and out through the Golden Gate during each tidal cycle. That large amount of seawater mixes with the fresh water that enters as Delta outflow to form a long salinity gradient. During each summer as Delta outflows are reduced, the gradient moves upstream to the western edge of the Delta. Normally, it is kept out of the Delta by water releases from Shasta and Oroville reservoirs. When the fall rains increase Delta outflows, the salinity gradient is again pushed downstream to a location depending on the magnitude and duration of the outflow.

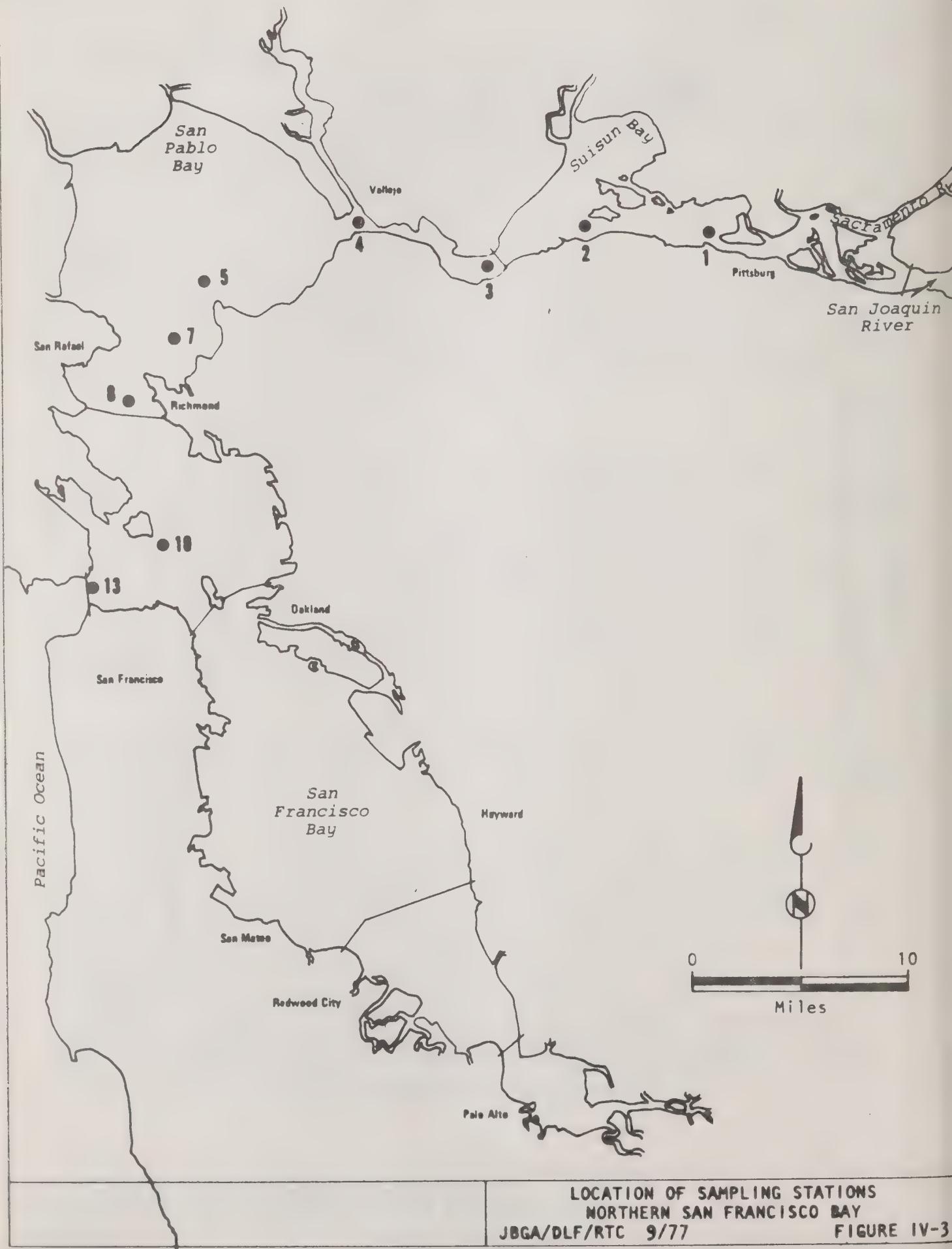
The relationship between net Delta outflow and chlorosity as a function of distance from the Golden Gate in the northern reach of the Bay is shown on Figure IV-2. (The procedure used to derive this relationship is described in Appendix A.) Station locations are shown on Figure IV-3.

One consequence of decreased future Delta outflow magnitudes is that the distribution of the Bay's biota will almost certainly change in response to the resulting increased Bay salinities. During 1963, representative of a normal year (actual annual average outflow was 34,300 cfs), and 1964, representative of a much drier year (actual annual average outflow, excluding December, was 11,800 cfs), Ganssle (1966) sampled fish with small mesh trawls and gill nets and found that marine forms moved farther upstream during the drier 1964. During 1964, the Pacific herring, Clupea pallasi, and Northern anchovy, Engraulis mordax, migrated farther upstream, juvenile bay shrimp appeared earlier and in greater number in Suisun Bay, and market crabs (Cancer



DISTRIBUTION OF CHLOROSITY IN NORTHERN  
SAN FRANCISCO BAY AS A FUNCTION OF NET DELTA OUTFLOW  
JBGA/RIB/RTC 8/77

FIGURE IV-2



magister), which were almost completely absent in 1963, were common in San Pablo Bay in 1964 and even moved into western Suisun Bay during that drier year. However, if future long-term average fall, winter, and spring Delta outflows are to decrease below historic levels as Delta exports increase (see Table IV-1), San Francisco Bay should become more saline than under historic outflow conditions, especially east of Carquinez Strait where chlorosity is very sensitive to Delta outflow (see Figures IV-2 and IV-3). Such a change should affect the distribution of Bay aquatic species, many of which are sensitive to salinity.

Another result of decreased future Delta outflows will be reduced occurrence of salinity stratification and its resulting circulating currents in San Francisco Bay. Not only does freshwater discharge from the Delta provide the major control of salinity north of the Bay Bridge, it is a major factor in affecting seasonal salinity variation in the South Bay (McCulloch et al., 1970). Also, except for areas in the west Delta, salinity stratification does not apparently occur until sufficiently large Delta outflows occur.

For the South Bay, it has been reported (Hugo B. Fischer Inc. and Waterfront Design Associates, 1977) that, after a prolonged period of low Delta outflow of about 5,000 cfs, a Delta outflow of at least 10,000 cfs is required to cause weak salinity stratification north of San Bruno Shoal in the South Bay, but that 40,000 cfs is necessary to stratify the South Bay below San Bruno Shoal. The decline in South Bay salinity is more sensitive to peak outflow magnitude and to the history of previous flood events than to the total outflow volume for a given time period. For example, a 60,000 cfs Delta outflow for 20 days will have a greater effect on salinity than will a flow of 30,000 cfs for 40 days. Also, a flood flow will affect salinity more if preceded by a long period of low outflows than if the flood outflow occurs soon after a prior flood flow. For the South Bay, the rate of recovery of salinity is about 2 parts per thousand (ppt) per month up to about 29 ppt; thereafter, roughly four months is required for salinity to rise from 29 to 31 ppt.

For the Central Bay (as depicted on Figure II-1), Kelley and Tippets (1977) report surface to bottom salinity differences of only about 1 ppt during controlled low summer outflows of around 4,000 cfs, with only modest rises in salinity differences of from 2 to 4 ppt and 5 to 7 ppt for monthly mean Delta outflows of 16,800 cfs and 67,200 cfs, respectively. Although the North Bay seems difficult to stratify, the United States Corps of Engineers

detected slight net upstream bottom currents and net downstream surface currents in the Fall of 1956 when Delta outflow was 10,800 cfs and surface to bottom salinity difference was only 1 ppt in the North Bay (Peterson et al., 1975).

In San Pablo Bay, high winds, shallow water depths, and great exchange with the North Bay are all significant obstacles to salinity stratification and resultant circulating currents. For Delta outflows up to about 33,600 cfs, Storrs et al., (1961-62, 1962-63) found salinity differences in San Pablo Bay to be usually no larger than in the North Bay. However, a U. S. Geological Survey seabed drifter study (Conomos et al., 1971) found evidence of some year-round upstream bottom currents during March 1970 to March 1971, when Delta outflows ranged from 5,040 to 55,500 cfs.

For Carquinez Strait, Delta outflows of 11,000 to 35,000 cfs resulted in net upstream and downstream currents below and above mid-depth, respectively. At a larger flow of 81,000 cfs, upstream flows were eliminated and all salinities were reduced to nearly zero (Peterson et al., 1975). Thus, Carquinez Strait experiences circulating currents until Delta outflow increases to some level between 35,000 and 81,000 cfs, and possibly also at flows below 11,000 cfs.

Suisun Bay is stratified even during low summer Delta outflows. At flows much above 16,600 cfs, eastern Suisun Bay is destratified and becomes essentially all fresh water. In contrast, the western end is well stratified at Delta outflows ranging from 75,600 to 10,100 cfs and possibly even less (Kelley & Tippets, 1977).

Thus, future decreases in Delta outflow should reduce the occurrence of salinity stratification in the Bay. This may affect Bay environmental quality because the circulating currents resulting from salinity stratification have been designated as being important for removing pollutants from Bay waters (McCulloch et al., 1970), for controlling basic biological productivity (Arthur, 1975; Ball, 1975) and for transporting and distributing larval invertebrates, fish, and their food supplies (Pritchard, 1951; Cronin, 1967). Removal of pollutants from the Bay is important since the Bay has been found to contain high levels of various toxic heavy metals and, in the South Bay, pesticides and hexane extractables appear to be accumulating (State Water Resources Control Board, 1975).

### Nutrients

Dissolved nitrogen, phosphorus, silica, and other constituents necessary for phytoplankton and microorganism growth enter San Francisco Bay from several sources: sea water through the Golden Gate, local runoff, waste treatment plant discharges, and Delta outflow. Although future decreases in Delta outflow will reduce nutrient contributions to the Bay, anticipated increases in agricultural drainage and waste treatment plant discharge volumes should more than make up for at least some of these Delta outflow nutrient declines (State Water Resources Control Board, 1975). For nitrogen and phosphorus, an attempt to relate Delta outflow to nutrient concentrations in the Bay north of the Golden Gate produced no statistically meaningful relationship. In the South Bay, however, McCulloch et al. (1970) found during a wetter than normal year that seasonally variable phosphate concentrations could not be explained by tidal action or loading from the San Jose sewage treatment plant but instead appeared to be inversely related to Sacramento River discharge, which represents about 85 percent of Delta outflow. That is, an increase or decrease in outflow was accompanied by a decrease or increase in phosphate concentration. It thus appears that high Delta outflows may be an important factor in removing soluble waste materials from the South Bay.

Delta outflows also apparently contribute large amounts of organic detritus to San Francisco Bay. No one has yet made any direct measurements or estimates of detritus input to the Bay, but biologists have often observed large amounts of such organic materials in fine mesh collecting nets and water samplers near the bottoms of the Bay and Delta. Although phytoplankton is the major primary producer in most large estuaries of North America, detritus may play a major microorganism nutrient role in the Bay-Delta system, especially where currents are too strong for phytoplankton growth. It seems reasonable to assume that large amounts of terrestrial detritus enter the Bay during high Delta outflows, and that major decreases in Delta outflow will reduce that detritus supply.

Another important nutrient found in Delta outflow waters is silica. This substance is consumed in great quantity to produce the hard shells of diatoms, the algae group which makes up at least 90 percent of the Bay's phytoplankton. In normal rainfall years, Delta outflow supplies the Bay with at least twice the silicate contributed by waste discharges and ocean waters, as shown in Table IV-2. During winter and spring months when Delta

outflow is at its peak, Suisun Bay and San Pablo Bay silicate levels are higher than those in the North and South bays. In summer and fall, silicate levels are usually about as low as ocean silicate levels throughout the Bay. Thus, it is apparent that Bay silicate levels are more sensitive to seasonally variable Delta outflow than to relatively constant tidal cycles and waste discharges. The relationships between net Delta outflow and silica levels at various locations north of the Golden Gate are shown on Figure IV-4.

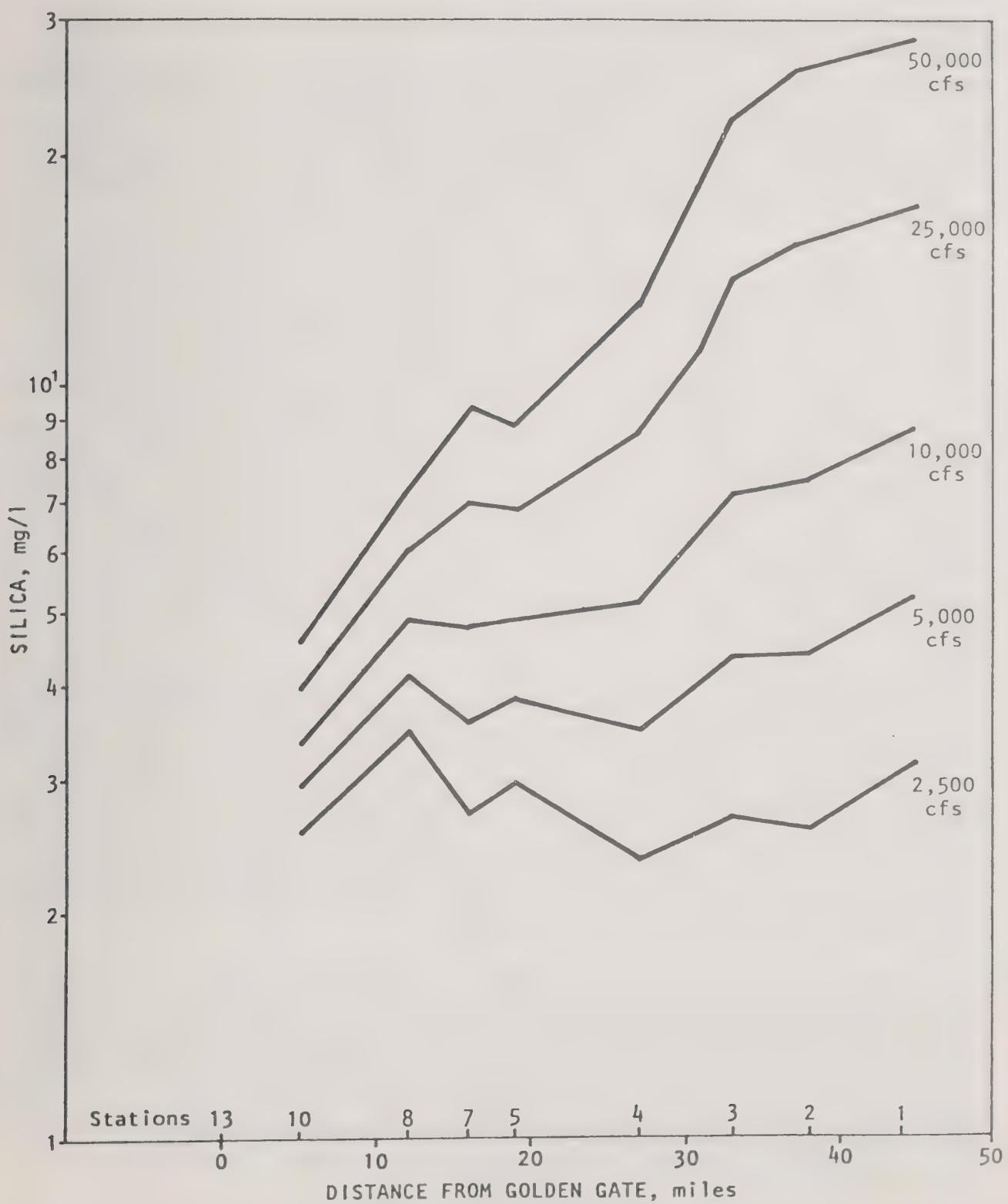
TABLE IV-2

MONTHLY SILICATE CONTRIBUTIONS  
TO SAN FRANCISCO BAY\*

Source of Contribution	Silicate Contribution $10^6$ lb
Ocean	26.4
Waste discharges	2.0
Delta: mean monthly outflow rate, cfs	
2,000	4.7
5,000	11.8
20,000	47.1
50,000	118.1
100,000	236.2
150,000	354.3

\*Table adapted by Kelley and Tippets (1977) from data of Conomos and Peterson (1975) who reported mean freshwater and ocean water silicate concentrations as 300 $\mu$ g atoms/l and 30 $\mu$ g atoms/l, respectively.

Future decreases in Delta outflows are bound to reduce winter and spring silica concentrations in Suisun and San Pablo bays and will likely also reduce silica levels in the North Bay and the north end of the South Bay during wet years (Kelley & Tippets, 1977).



DISTRIBUTION OF SILICA IN NORTHERN SAN FRANCISCO  
BAY AS A FUNCTION OF NET DELTA OUTFLOW  
JBGA/RIB/RTC 8/77

FIGURE IV-4

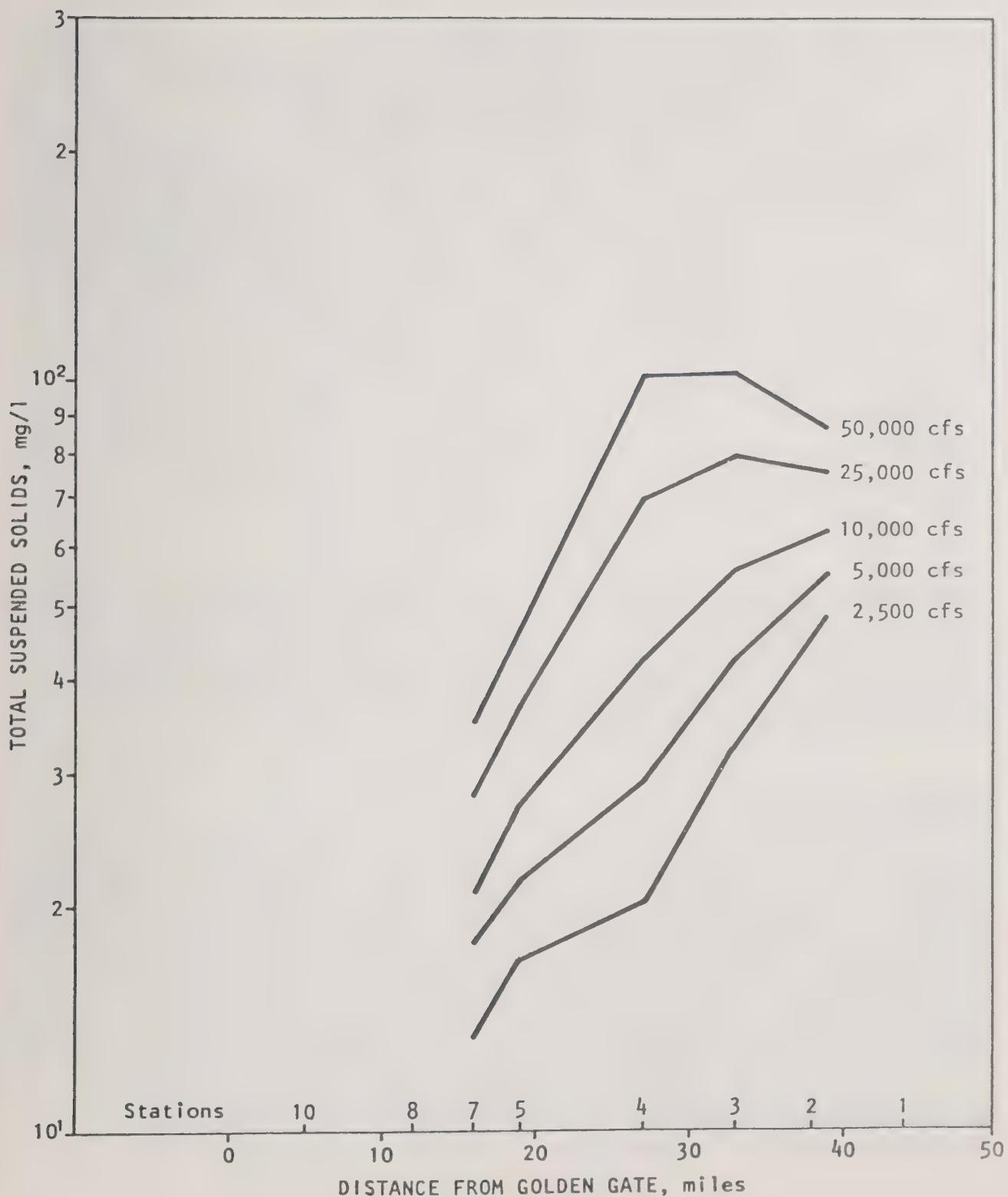
### Suspended Sediments

Delta outflow is the largest source of suspended sediment for the Bay. Over 75 percent of Bay sediment enters along with large winter and spring outflow from the Delta, and peak Bay suspended solids and turbidity levels occur at these times. For northern Bay waters, a relationship between total suspended solids and net Delta outflow was derived and is shown on Figure IV-5.

High Delta outflows transport some new sediment into the North Bay and sometimes into the South Bay, but much sediment initially settles in the shallows of Suisun and San Pablo bays. Wind and wave action resuspend sediment deposits from shallow areas while strong Bay tidal currents scour and resuspend deposits in deeper water. The finer fraction of resuspended sediments is transported to the ocean or deposited where resuspension forces are weak, leaving coarser compacted sediments on the bottom. Such deposits are relatively difficult to resuspend. Thus, reduced Delta outflow will reduce both suspended sediment contributions to the Bay as well as the amount of material resuspended from the bottom (Krone, 1976). Sediment resuspension is the most important process in maintaining Bay turbidities in late spring through fall, and the U. S. Corps of Engineers (1975) has estimated that about 15 times as much material is resuspended each year as actually enters the Bay with river inflow.

Reduced Delta outflows should result in decreased suspended solids and turbidity levels. Limited data comparing these parameters for two multi-year periods representing different levels of net Delta outflow support this belief, as shown in Table IV-3. This consequence of decreased Delta outflows may be very important to Bay environmental quality because: (1) increased water clarity could affect growth of phytoplankton and other algae, and (2) because suspended sediments have the capability to assimilate pollutants such as heavy metals and pesticides, any decrease in Bay suspended sediment levels may result in higher unassimilated pollutant concentrations in the Bay environment.

The factors limiting algae production in the Bay are not precisely known. It has generally been supposed that light penetration is the limiting algae growth factor in San Francisco Bay, and that algal productivity will increase if Bay waters become less turbid. However, evidence suggests that algae populations will decrease as Delta outflows decrease. Data for the low Delta outflow years of 1976 and 1977 indicate that the standing algae population in Suisun Bay decreased in spite of increased water transparency (State Water Resources Control Board, 1978).



DISTRIBUTION OF TOTAL SUSPENDED SOLIDS IN NORTHERN  
SAN FRANCISCO BAY AS A FUNCTION OF NET DELTA OUTFLOW  
JBGA/RIB/RTC 8/77

FIGURE IV-5

TABLE IV-3

HISTORICAL MEAN BAY SUSPENDED SOLIDS CONCENTRATIONS  
AND SECCHI DISC TRANSPARENCIES FOR  
TWO DIFFERENT LEVELS OF DELTA OUTFLOW

Location	1970-1975 30,900 cfs Annual Average Outflow		1960-1964 19,900 cfs Annual Average Outflow	
	Suspended Solids, mg/l	Transparency ft	Suspended Solids, mg/l	Transparency ft
South Bay	-	2.4	42	2.7
North Bay	36	4.2	18	4.6
San Pablo Bay	77	-	45	1.6
Suisun Bay	82	0.78	65	0.90

Source: U. S. Corps of Engineers, 1975

Concerning sediment assimilation of pollutants, limited information on the capacity of Bay sediments to take up pollutants exists. However, the San Francisco Bay Basin Plan states that the equilibrium Bay heavy metals concentration is expected to triple (from 0.09 to 0.27 mg/l) from 1970 to 2000, partly as a consequence of reduced Delta outflows.

#### Anadromous Fishes

Decreased Delta outflows due to increased future upstream diversions also pose a threat to the anadromous fishes of the Bay-Delta system. Fish migrations and spawning runs have historically been timed to coincide with subsequent periods of good spawning and egg hatching conditions upstream and with production of large food supplies for juvenile fish as they move downstream through their nursery areas. High freshwater outflows into the Bay play an important role in transporting fish and maintaining these food supplies (Kelley & Tippets, 1977). For salmon, a critical factor controlling the size of adult spawning runs in the San Joaquin River system is the magnitude of flow in the spring. High flows during seaward migrations in spring have produced peak adult spawning runs 2-1/2 years later. Unfortunately, years of high

spring flow are now uncommon because of upstream water use. For striped bass, maintenance of high Delta outflows may affect survival by concentrating them in areas most conducive to their survival, by increasing their food supply, by diluting toxic waste discharges, or by maintaining high turbidities which likely minimize predation. Upstream diversions could decrease striped bass survival by removing bass or their food through diversion intake facilities. The net effect of further diversion on bass populations is presently unknown (Peripheral Canal Draft Environmental Impact Report, 1974).



## CHAPTER V

### PRINCIPAL FINDINGS AND CONCLUSIONS

San Francisco Bay is a complex body of water responding to ever-changing environmental inputs and conditions. Most of the research to characterize the Bay has been done within the last 20 years. Generally this research has been conducted with the purpose of understanding how the Bay would react to increased waste loads and to reduced Delta outflows. As a result of this research we now have a partial understanding of the important physical characteristics of the Bay, such as currents and salinity distributions, and a limited comprehension of a few biological relationships such as some aspects of fish productivity. For the most part, it cannot be precisely said what will happen to pollutant concentrations, algae growth, fish life, and other parameters if Delta outflows are further regulated. The uncertainty surrounding the effects of future Delta outflows upon the Bay increase in rough proportion to the extent that future Delta outflows will vary from outflows during the last 20 years when most of the data were collected. The principal issues relate to what extent flood flows will be allowed to enter the Bay or whether they will be captured in upstream reservoirs and what minimum outflows will be provided during the dry season. Based upon available information and known environmental relationships the following conclusions can be drawn.

#### HISTORICAL AND PROJECTED DELTA OUTFLOWS

Because of the expected increases in upstream water diversions, the Delta outflows in the year 1990 are predicted to be 58 percent less in a normal year, 38 percent less in a wet year, and 52 percent less in a dry year. Projected 1990 Delta dry year outflows of 2.25 million acre-feet are only half of the previous low-water year of 1923-1924. Flows less than or equal to the projected 1990 normal year outflow have occurred only once from 1940 to 1976. Because research and extensive data collection in the Delta did not occur until relatively recently, there has not been ample opportunity to study the behavior of the Bay under projected future Delta outflows and to verify conclusions concerning specific effects.

#### EFFECT OF DELTA OUTFLOW ON FISH

During historical dry years the character of the fish life in the Northern Bay above Carquinez Strait became more marine instead of its usual freshwater character. For example, in 1964 when the outflow was approximately one-third of the historical normal and approximately 95 percent of the projected 1990 normal year, marine organisms moved into western Suisun Bay. The exact relationships between fish populations and decreased outflows due to increased diversions remain largely unknown at this time. However, it has been shown that high Delta outflows are important to salmon and striped bass. High flows produce peak salmon spawning runs two and one-half years later. Increased diversions from the Delta may decrease striped bass survival in the Bay by removing the fish or their food supply.

#### SILICATE CONTRIBUTIONS TO THE BAY

Silicate is used in large quantities to produce the hard shells of diatoms, the predominant phytoplankton species in the Bay. Phytoplankton is important to the biological food chain in the Bay. Delta outflow now provides approximately two-thirds of the total silicate to the Bay. Under projected future conditions this total would be reduced by 40 percent in 1990. This may possibly reduce the production of diatoms in the Bay, but this effect remains to be demonstrated.

#### ALGAE PRODUCTION AND ASSIMILATION OF POLLUTANTS

The factors limiting algae growth in the Bay have not yet been determined. Until recently, many investigators felt that light penetration or water clarity was generally the limiting algae growth factor in the Bay and that algae productivity would increase if Bay waters became less turbid. However, recent evidence indicates that Suisun Bay algae populations declined from previous levels during the years 1976 and 1977, when annual Delta outflow was very low and estuarial water clarity increased over previous years. Thus, the effects of Delta outflow on algae production are unclear at present. However, it is expected that chronically reduced Delta outflows will result in a decline in Bay turbidity. This is because most of the suspended material in the Bay has originally come from the Delta during high flow periods. Reduced Delta outflows, especially the flood flows, will reduce suspended

solids contributions to the Bay. This will also reduce the material available to be resuspended from the bottom due to wind action. Consequently turbidity in the Bay would gradually be reduced if flood flows are not allowed to come into the Bay and replace the suspended material lost to the ocean.

A related effect is that there will be less capacity for assimilation of heavy metals by the suspended sediments and removal from the water column due to settling. It is estimated that the concentrations of heavy metals will triple in the Bay from 1970 to 2000, partly as a consequence of reduced Delta outflows.

#### EFFECT ON STRATIFICATION

An effective way to improve water circulation in the South Bay is to have the Bay in a stratified condition, whereby fresh water flows on top of the heavier salt water for a period of time, thereby setting up a current pattern. To stratify the South Bay after a prolonged period of low flow a Delta outflow of at least 40,000 cfs is required. What is important is the peak rate, not the total volume of Delta outflow. The effects of winter flood flows from the Delta persist for four to six months in the South Bay. The extent to which a stratified condition reduces pollutant concentrations in the South Bay is unknown at this time.

One benefit of stratification in the Bay is that it causes bottom currents to flow upstream toward the Delta. This moving water is believed to be essential in transporting fish and their food supply, helping to maintain fish productivity.

#### NEED FOR FURTHER RESEARCH

There exists in the records and files of many public agencies a substantial amount of water quality information, but very little data are conclusive regarding the affects of Delta outflow on the quality of San Francisco Bay. Much of this information has not been analyzed, but indications are that its analysis would be helpful to determine the biological effects of long-term changes in Bay and Delta hydraulic conditions; however, the baseline information upon which to draw conclusions regarding the effects of permanently reduced Delta outflow does not exist. Questions regarding the significance of outflow have been the subject of

much controversy and great concern on the part of the many residents of the Bay Area who fear that the diversion of water from the Delta to areas of central and southern California will permanently and adversely alter the quality of San Francisco Bay.

This study has indicated that there will be long-term changes, and that these changes will produce changes in biological communities. The extent and magnitude of these changes has yet to be assessed. State regulatory and planning agencies should have access to a much more detailed and long-term data base that has been developed specifically to analyze the potential effects on the Bay. Other estuarine systems have been and are the subject of much more extensive water quality research than is now being conducted for San Francisco Bay. Such research should be coordinated with effluent and receiving water monitoring programs as well as non-point source control studies. Research being conducted by independent Federal and academic institutions could contribute greatly to a common body of knowledge, providing there was improved communication, exchange of information, and a central office that provided a repository for information and that coordinated and recommended future research projects. The institutional aspects of such an effort will require analysis, but it should be developed as part of continuing areawide water quality planning for the San Francisco Bay-Delta area.

The following are four areas in which additional research and data collection can provide much needed information on the effects of Delta outflow on the quality of San Francisco Bay. These elements should be expanded into a regional work plan to provide the information that is essential for future decision-making.

1. Delta outflows required to maintain or enhance present fish species diversity and productivity in the Bay.
2. Extent to which Delta outflow can be regulated and still provide a balance between sufficient phytoplankton production, maintaining existing biological relationships, and algae blooms prevention.
3. Quantify the relationship between Delta outflow and the concentration of heavy metals and other toxicants in the Bay and estimate the impacts of possible increases in concentration levels.

4. Study water circulation in the South Bay under various magnitudes of high Delta outflows and sequences of regulated flows. Develop relations between water quality in the South Bay and Delta outflow, local runoff, and wastewater discharges; and evaluate the sensitivity of changes in water quality to changes in Delta outflow.

Completion of this work should be timed to be used as input to decision-making regarding future Delta water diversion schedules. A long-term water quality monitoring program in the Bay will also be needed to verify that future increased regulation and diversion of Delta outflows from the Bay have not produced unacceptable consequences.



## APPENDIX A

### REFERENCES

Arthur, J. G., "Preliminary Studies on the Entrapment of Suspended Materials in Suisun Bay, San Francisco Bay-Estuary," pp. 17-36. In: R. L. Brown (ed.) Proceedings of a Workshop on Algal Nutrient Relationships in the San Francisco Bay and Delta. The San Francisco Bay and Estuarine Association and California Department of Water Resources. November 1973.

Ball, J. D., "Chlorophyll Levels in the Sacramento-San Joaquin to San Pablo Bay." Proceedings of Workshop on Algal Nutrient Relationships in the San Francisco Bay and Delta. The San Francisco Bay and Estuarine Association and State Department of Water Resources. November 1973.

Brown and Caldwell, Water Resources Engineers, and Yoder-Trotter-Orlob & Associates, Water Quality and Ecologic Models of the San Francisco Bay Delta System. June 14, 1974 (unpublished).

Conomos, T. J., D. S. McCulloch, D. H. Peterson, and P. R. Carlson, "Drift of Surface and Near Bottom Waters of the San Francisco Bay System: March 1970 through April 1971." U. S. Geological Survey Basic Data Contribution 22. 1971.

Conomos, T. J. and D. H. Peterson, "Longitudinal Distribution of Selected Micronutrients in Northern San Francisco Bay During 1972," pp. 103-126. In: R. Brown (ed.) Proceedings of a Workshop on Algal Nutrient Relationships in the San Francisco Bay and Delta. The San Francisco Bay and Estuarine Association and State Department of Water Resources. November 1973.

Cronin, L. E., "The Role of Man in Estuarine Processes," pp. 667-690. In: G. H. Lauff (ed.) 1967 Estuaries. American Association for the Advancement of Science, Washington, D.C. 1967.

Ganssle, D., "Fishes and Decapods of the San Pablo and Suisun Bays," pp. 64-94. In: D. W. Kelley (ed.) Ecological Studies of the Sacramento-San Joaquin Estuary. California Department of Fish & Game, Fish Bulletin No. 133. 1966.

Hugo B. Fischer, Inc. and Waterfront Design Associates, The Effect of Delta Outflow on the Density Stratification in San Francisco Bay. Report prepared for Association of Bay Area Governments, Berkeley. June 1977. HBF-77/02.

Kelley, D. W., letter to J. B. Gilbert & Associates. March 7, 1978.

Kelley, D. W. and W. E. Tippets, Delta Outflow and San Francisco Bay. Report prepared for Delta Environment Advisory Committee, State Department of Water Resources. April 1977.

Krone, R. B., "Ultimate Fate of Suspended Material in Estuaries." Presented to ASCE Specialty Conference, Dredging and Its Environmental Effects, Mobile, Alabama. January 1976.

McCulloch, D. S., D. H. Peterson, and T. J. Conomos, "Some Effects of Freshwater Inflow on the Flushing of South San Francisco Bay: A Preliminary Report." U. S. Geological Survey Circular 637-A. 1970.

Messersmith, J., Fishes Collected in Carquinez Strait in 1961-62. California Department of Fish & Game, Fish Bulletin No. 133. 1966.

Peterson, D. W., T. J. Conomos, W. W. Broenkow, and P. C. Doherty, "Location of the Nontidal Current Null Zone in Northern San Francisco Bay." Estuarine and Coastal Marine Science, 3:1-11. 1975.

Pritchard, D. W., "The Physical Hydrography of Estuaries and Some Applications to Biological Problems." Trans. North American Wildlife Conference, pp. 368-376. 1951.

Roos, Maurice and Department of Water Resources, Estimates of Delta Water Supply and Disposal. Memorandum to R. Williams and C. McCullough. December 16, 1971.

Selleck, R. E., et al., "Physical and Hydrological Characteristics of San Francisco Bay," Volume IV of A Comprehensive Study of San Francisco Bay, Sanitary Engineering Research Laboratory, University of California, SERL Report 65-10. 1966a.

Selleck, R. E., et al., "A Model of Mixing and Diffusion in San Francisco Bay," Volume III of A Comprehensive Study of San Francisco Bay, Sanitary Engineering Research Laboratory, University of California, SERL Report 67-1. 1966b.

State of California, Department of Public Works, Variation and Control of Salinity in Sacramento-San Joaquin Delta and Upper San Francisco Bay. Bulletin No. 27. 1931.

State of California, Department of Water Resources, Estimated Delta Outflow Under Historic 1980 and 1990 Conditions. In letter to J. B. Gilbert & Associates. March 21, 1977.

State of California, Department of Water Resources, Draft Environmental Impact Report: Peripheral Canal Project. August 1974.

State Water Resources Control Board, Draft Environmental Impact Report for the Water Quality Control Plan: Sacramento-San Joaquin Delta and Suisun Marsh. March 1978.

State Water Resources Control Board, Water Quality Control Plan Report: San Francisco Bay Basin (2). April 1975.

Storrs, P. N., E. A. Pearson, and R. E. Selleck, A Comprehensive Study of San Francisco Bay. Appendix for 1961-62. University of California at Berkeley, Sanitary Engineering Research Laboratory. SERL Report 63-4. April 1963.

Storrs, P. N., E. A. Pearson, and R. E. Selleck. A Comprehensive Study of San Francisco Bay. Appendix for 1962-63. University of California at Berkeley, Sanitary Engineering Research Laboratory. SERL Report 64-4. April 1964.

U. S. Army Corps of Engineers, Maintenance Dredging Draft Federal Navigation Projects. San Francisco Bay Region. 1975.



## APPENDIX B

### DERIVATION OF RELATIONSHIPS BETWEEN VARIOUS WATER QUALITY PARAMETERS AND DELTA OUTFLOW FOR NORTHERN SAN FRANCISCO BAY

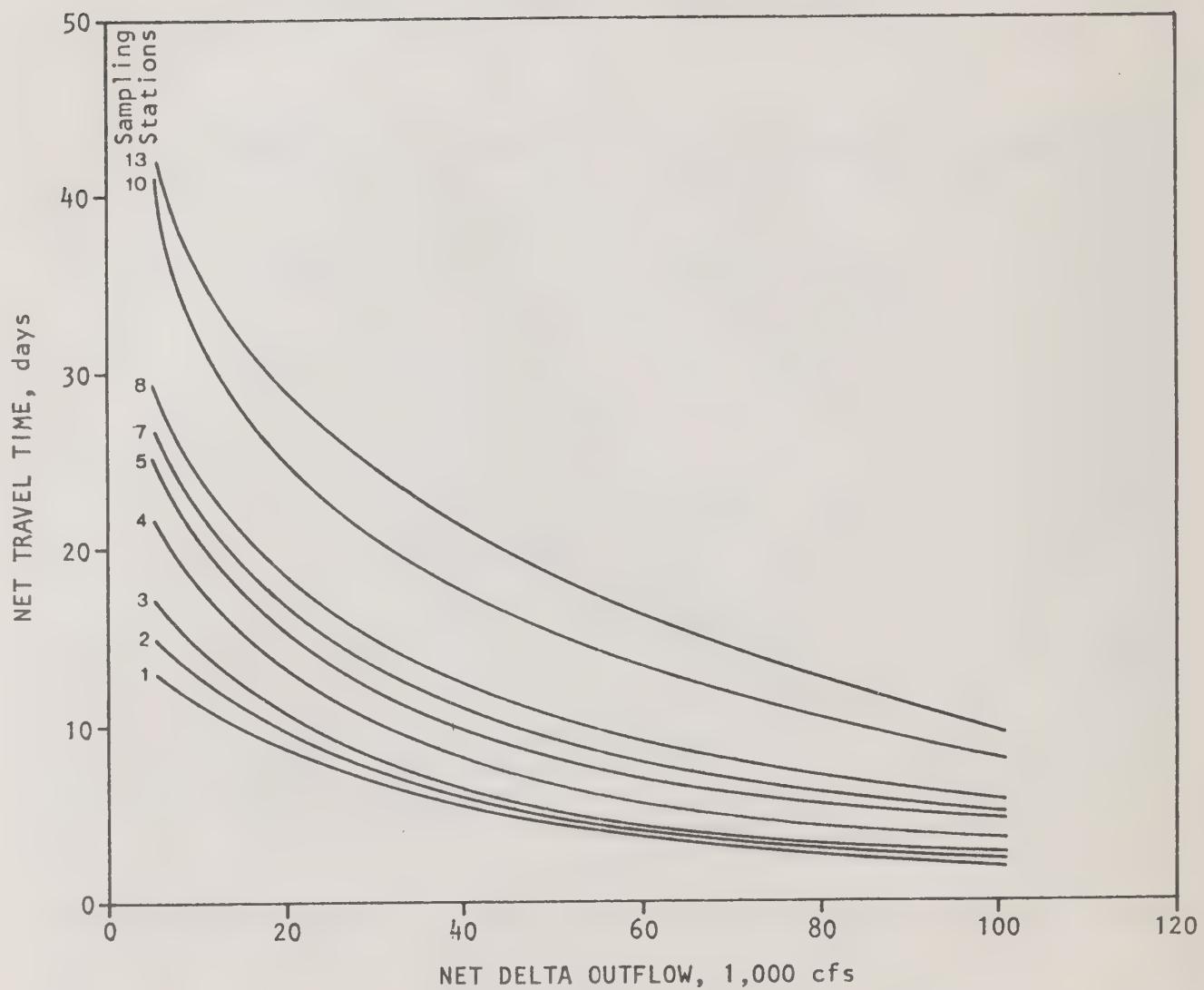
Relationships between various Bay water quality parameters (nitrate, phosphate, suspended solids, silica, and chlorosity) and Delta outflow in the northern Bay were derived by using University of California Bay Study water quality data at monitoring stations north of the Bay Bridge and the estimated daily instantaneous Delta outflow responsible for the water quality level at each Bay station. Data for Stations 1, 2, 3, 4, 5, 7, 8, 10, and 13 on Figure IV-3 were used in this analysis. Net advective velocities between various northern Bay sampling stations, as a function of net Delta outflow, were obtained from results (from a previous study) of the link-node mathematical model of San Francisco Bay. Total travel time from the Sacramento River gaging station to each monitoring station was determined for each of three Delta outflows, and curves were fit by eye to each station's point set. These relationships are shown on Figure B-1. Daily Delta Outflow Index (DOI) records were examined to yield the DOI for a day having water quality data, and entering Figure B-1 with that day's DOI resulted in a travel time delay from the Sacramento gaging station to each sampling station. For a given sampling station, the resulting travel time delay was subtracted from the water quality sampling date to obtain an earlier date and that day's corresponding DOI. If DOI was not very constant in the neighborhood of the earlier date, the time delay was chosen to correspond to a previous DOI which, via Figure B-1, best satisfied the equation:

$$\text{Date of water quality} \approx \text{Travel time delay} + \text{Date of previous DOI}$$

(i.e., August 25  $\approx$  11 days + August 14)

Because DOI is not necessarily a very accurate estimate of Delta outflow, daily Delta outflow responsible for daily water quality values was adjusted using the California Department of Water Resources monthly Delta outflow data via:

$$\text{Daily Delta Outflow} = \frac{(\text{Daily DOI}) (\text{DWR monthly Delta outflow})}{(\text{Monthly total of daily DOI values})}$$



NET TRAVEL TIME FROM SACRAMENTO RIVER GAGING STATION  
AT SACRAMENTO TO VARIOUS LOCATIONS IN NORTHERN  
SAN FRANCISCO BAY AS A FUNCTION OF NET DELTA OUTFLOW  
JBGA/RIB/RTC 8/77

FIGURE B-1

Thus, for a given station each day's water quality data could be paired with an approximate causal Delta outflow. For each station, all data for each water quality parameter was regressed in terms of derived outflows to obtain a best-fit equation of water quality versus outflow. Relationships were developed for nitrate, phosphate, TSS, silica, and chlorosity. Results are shown on Figures III-9 and III-10.





U.C. BERKELEY LIBRARIES



C124924450